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OF THE

NATIONAL FIRE PROTECTION ASSOCIATION

"To Promote the Science and Improve the Methods of Fire Protection and Prevention."

PUBLISHED QUARTERLY AT BOSTON, MASS., BY THE
NATIONAL FIRE PROTECTION ASSOCIATION

Printed in U. S. A.

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Vol. 37 October, 1943 No. 2

QUARTERLY

OF THE

National Fire Protection Association

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National Fire Protection Association

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A NON-PROFIT TECHNICAL AND EDUCATIONAL ORGANIZATION

To promote the science and improve the methods of fire protection and prevention.

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Table of Contents.

ALBERT T. BELL ..... FRONTISPIECE

GULF HOTEL FIRE. *H. Oram Smith* 83

FIRE PROTECTION IN RELOCATION CENTERS. *William E. Hoffman* 93

TOWN PLANNING LESSONS OF THE FIRE BLITZ. *Eric L. Bird, M.C., A.R.I.B.A.* 100

TREATMENT OF BURNS. *Charles C. Lund, M.D.* 111

EXPLOSIVE PROPERTIES OF METAL POWDERS. *Hylton R. Brown* 117

CONGOLEUM-NAIRN CO. EXPLOSION 127

VENTING OF TANKS EXPOSED TO FIRE. *James J. Duggan, G. H. Gilmour and P. F. Fisher* 132

THREE DEFENSE PLANT FIRES. *J. T. W. Babcock* 154

SOYBEAN PLANT FIRE RECORD. *Warren Y. Kimball* 157

FIRES AND FIRE LOSSES CLASSIFIED, 1942 170

Reports of fires appearing in the Quarterly are copies of or extracts from written reports forwarded to the Association. This Association, as a body, is not responsible for the statements or opinions of any of its members.

ALBERT T. BELL

Chairman, N.F.P.A. Board of Directors, 1922-1943.

Mr. Bell's sudden death on September third came as a great shock to the N.F.P.A. official family and to the many members of the Association who knew him. Mr. Bell rendered distinguished service to the cause of fire protection and fire prevention. His contributions to the growth and prestige of our Association were great and he possessed the enduring affection of all of us who were fortunate enough to know him.

The Quarterly

Vol. 37 October, 1943 No. 2

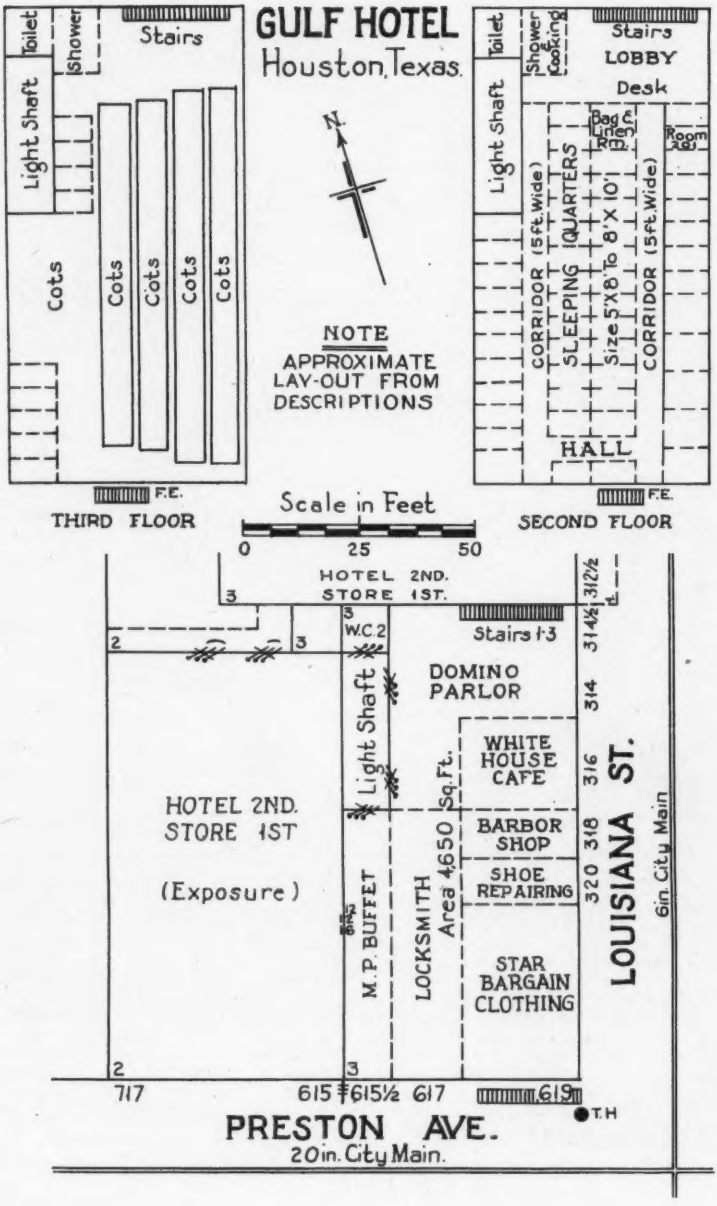
Gulf Hotel Fire.

By H. Oram Smith (Member N.F.P.A.),
Manager, Texas Inspection Bureau.

The Houston fire department responded to a midnight alarm from the older section of the business district on the night of September 7, 1943. It was a routine night run that would go into the records for a nominal fire loss to an old building of relatively small value. The unusual feature was the unexpected casualty list of 54 dead and 8 critically injured in a small fire of short duration. The building, which had been a rooming house for 25 years, was graced with the name Gulf Hotel, but it was literally a human hive where 145 "registered guests" were bedded down on two floors, each floor having only about 4000 sq. ft. of habitable space.

It was another tragedy of the rooming house class, one of several other "hotel" investments under the same operating company that caters to the less fortunate class of men, many of them old, ailing or crippled, with arms or legs missing. There was about an equal number of regular roomers and transients. For 20 cents they could sleep side by side on rows of iron cots on the third floor; for 25 cents they could have a cot in a wooden box 5 x 8 ft., and for 35 or 50 cents a larger box up to 8 x 10 ft. with chair and table. The two small floor areas were arranged to accommodate 87 of the so-called rooms and 46 open space cots.

The Gulf Hotel is an old three-story brick building on a corner location with an overall size of 50 x 100 ft., but with a 10 x 35 ft. space cut out for a light shaft for second and third floors adjoining the building on the west. The outside walls are of brick, floors and roof of wood on light wooden joists, and ceilings of wood and plaster board. The grade floor space, 615-19 Preston Ave. and 314-20 Louisiana St., was occupied by seven small mercantile tenants sepa-


GULF HOTEL
Houston, Texas.
N
NOTE
APPROXIMATE LAY-OUT FROM DESCRIPTIONS
Toilet
Shower
Stairs
Light Shaft
Cots
Cots
Cots
Cots
Cots
F.E.
THIRD FLOOR
Toilet
Shower
Cooking
Stairs
LOBBY
Desk
Light Shaft
CORRIDOR (5ft. Wide)
SLEEPING QUARTERS
Size 5'X8' To 8'X10'
Bag Linen
Room
CORRIDOR (5ft. Wide)
HALL
F.E.
SECOND FLOOR
Scale in Feet
0 25 50
HOTEL 2ND. STORE 1ST.
W.C.
Stairs
DOMINO PARLOR
WHITE HOUSE CAFE
BARBOR SHOP
SHOE REPAIRING
STAR BARGAIN CLOTHING
Light Shaft
Sq. Ft.
HOTEL 2ND. STORE 1ST
(Exposure)
M. P. BUFFET
LOCKSMITH
Area 4,650
LOUISIANA ST.
6in. City Main
312½
314½
314
316
318
320
717
615
615½
617
619
T.H
PRESTON AVE.
20in. City Main.

This picture was taken about 2 A.M., when the fire was at its height, from the Louisiana Street side of the hotel.

Loss of life in this fire was clearly due to lack of adequate exit facilities. While some means of escape was provided on both ends of the sleeping areas, thus providing two ways of escape as specified by the N.F.P.A. Building Exits Code, exit arrangements were seriously defective as measured by the standards of the Building Exits Code, which specifies enclosed stairways, adequate signs and lighting of exits, and some sort of an alarm system to arouse sleeping occupants. Where fire escapes are used, the Building Exits Code specifies convenient means of access and other features of construction comparable to inside stairways. Such features were grossly inadequate in this fire.

The Gulf Hotel the day following the fire.

rated by frame or plaster partitions, and the two upper floors by the rooming house.

There was a single wooden stairway against the north wall, extending from the third floor to the sidewalk on Louisiana St. This interior stairway extended from the street to the second floor between a brick and plaster wall and a plaster partition, and from the second to the third floor between a brick wall and a frame partition. Both flights were open at the upper and lower end; the street end had a door frame and transom but no door (see photograph on page 89). The stairs were 58 in. wide between walls and 48 in. between hand rails on each side. A witness at the subsequent investigation of the fire testified that it was normally an adequate, unobstructed exit, but that because the fire started near the stairway, access to the stairs was soon cut off, and most of the roomers were forced to use the only outside fire escape on the south, or Preston Ave. wall.

This fire escape was a steel stairway, 25 in. wide with hand rails 20 in. high, and with platforms 35 x 37 in. at the second and third floors, level with window sills. The escape was anchored at second and third floor levels, with a swinging extension from the second floor platform to the street. A steel scaling ladder extended from the top platform of the fire escape up over the coping of the roof.

The fire escape was reached through narrow, 20-in. wide windows, of the two-piece lifting type, set in pairs, with sills 20 in. above the floor level. On

the night of the fire it was unusually hot, and the windows were probably open to full height, but window screen wire mesh was tacked to the outside of the 24-in. frames. A witness said he kicked a hole through the screening and tore the wire off for others to follow. The second floor access to the fire escape was through one of the small room enclosures, but the third floor exit was from the open floor dormitory.

These escapes complied with the state fire escape law for a building of this size, except for the lack of red exit lights; it is reported that the fire marshal ordered lights installed on August 24, but the order had not been obeyed.

The second floor was a labyrinth of wooden partitions cut off below the ceiling, forming rows of cubbyholes from 5 x 8 to 8 x 10 ft. for sleeping rooms. They were arranged along the east and west walls facing narrow aisles, with other rows back to back facing the same aisles. There were a few similar sleeping rooms on the third floor, but that floor was mainly an open ward. Similar wooden partitions enclosed shower rooms on both upper floors, and a 10 x 12 linen and baggage room behind the desk on the second floor. The lobby and desk was a small space at the north end of the second floor, separated from the sleeping section by a wooden partition. Access to the street and to third floor was by the one interior stairway from the lobby.

Housekeeping conditions were poor; the congestion due to such crowded quarters contributed to a lack of cleanliness and order. There was the usual amount of electric wiring defects with portable cord extensions; cooking on hot plates was said to be general among the regular tenants, although supposed to be prohibited except in the shower bathrooms. There was no doubt an accumulation of old newspapers, clothing and personal junk in these compartments, especially among the regular tenants. Something of that nature served as tinder to touch off the mattresses and partitions in quick succession, for the fire to travel so fast and trap inmates in their beds. There is no evidence of any regular "delousing" system, but there was a 5-gal. can of insecticide with a naphtha base used to spray mattresses, and the iron cots were given an occasional blowtorch spraying to kill vermin. This insecticide was stored in the linen and baggage room, along with mops, brooms, rags, and odd junk. A few spray guns were available for the guests to use as they found necessary; it is possible that the mattresses and partitions had a film of residue from the spray material that served to quicken spread of fire. It was claimed that chemical fire extinguishers were installed on second and third floors, but none was found and none seen in use.

It is reported that some time around midnight a mattress was ignited from a cigarette in Room 201 on the second floor near the lobby partition wall. The night clerk put the fire out with water and immersed the sheet in a tub in the bathroom. Some time later, estimated to be from 30 minutes to an hour, he was attracted to the third floor by a disturbance and complaint

Preston Avenue end of second floor. Access to the fire escape was through a small room enclosure.

The main stairway, cut off by the flames in the early stages of the fire, was of little use except to carry down the dead.

that somebody was using a flashlight. He found nothing out of the way and was returning to the second floor by the stairway when he observed smoke and flame coming through the partition from the sleeping section into the lobby. It is apparent that the reflection from the flames through cracks in the floor above gave the impression of a flashlight to those on the third floor; this would indicate that the fire must have been burning for some minutes before the disturbance over the supposed flashlight started, and that the fire was already well under way when discovered.

The city manager has accepted the fire department's official report classing the fire as "accidental" due to carelessness. Testimony at the investigation of the fire seems to remove the re-ignition of the first mattress fire as a cause. The occupant of Room 201, who caused that first fire, was among the first to escape by the inside stairs. This occupant stated that he went to the linen room with the night clerk to get fresh linen and "believed" the clerk threw the burned sheet on a pile of soiled linen; the clerk's own story was that he took it to a bathroom and immersed it in a tub of water. The fire department is inclined to believe, as the linen room was the location of the fire, that the smouldering sheet caused the fire.

There were 21 witnesses examined at the investigation, having had from 30 days to 4 months' residence in the hotel. All of them testified that there were no exit signs or lights on either floor. It was also brought out at the investigation that the company which operates the Gulf Hotel made their own insecticide of oil, kerosene and naphtha, mixing it in one of their other properties and sending the one 5-gal. can, stored in the linen and baggage room. The fire department report refers to this or similar material being used by other operators in this building for over 15 years, and believes that the walls and partitions as well as the mattresses were well saturated with residue that would cause rapid spread of the fire.

The alarm was immediately sent in by telephone and recorded in fire department headquarters at 12:50 A.M. Two stations within 8 to 12 blocks sent apparatus at once, but on arrival both upper floors were involved, so a second alarm went in from a street box at 12:53 and a third at 12:56. The fire was tapped out at 3:15 A.M., with the two upper floors completely gutted and the roof partially collapsed. The fire department made a good stop for such an old combustible building. The entire block is of similar construction, and there were similar rooming houses in adjoining buildings on two sides. Had the fire communicated, the loss of life could have been much greater.

Among the tales of horror repeated by firemen and survivors there were plenty of comments on the progress and speed of the fire, but none were found who saw where or how the fire started. It is assumed that those close to the origin are among the dead. It evidently spread with great rapidity, and many were trapped in their beds to be suffocated or burned to death. Others fell over each other in the darkness and confusion of trying to reach an exit without guide lights, amid a labyrinth of partitions and narrow passages. Bodies were found piled about the floors and around the windows. A few jumped from windows, others were assisted down ladders after the firemen arrived. The inside stairway was beyond reach of most inmates, for it was cut off by the fire starting at that end of the building. This caused a congestion at the one fire escape window exit on each floor; *there were too many to use it in too short a time;* fire and smoke overcame those struggling for a chance at the window, and they dropped where they stood. The death list has reached 54, with 8 critically injured, 2 of whom are not given much chance to recover. There were others less seriously injured, the first hospital list being 25. The Red Cross held a mass funeral for the burial of 36 unidentified dead.

Apparently, nobody is officially responsible for this disaster; the fire chief is quoted by the press as saying there was no local law or fire prevention ordinance to govern. The building and occupancy does not conform to the present building code, but the code does not apply retroactively to a building and occupancy that has existed for many years, and neither the fire nor building department has any supplementary ordinance to apply. The state fire

Red Cross mass funeral for 36 unidentified dead.

escape law requires only one escape on a building of 5000 sq. ft., but that law does not contemplate such an area being used as a dormitory for 145 people. The state does not maintain an inspection force, and it seems no department of the city assumes the responsibility of checking up on interior conditions in relation to fire escapes. The fire marshal claims to have made a "fire inspection" of the premises on August 24, and apparently found no objection to the interior conditions, except the absence of exit lights. Under present conditions it is not likely that the owner could have had lights installed between August 24 and September 7, had he the wish to do so. It is just unfortunate that exit lights that would have been of value during the fire, but have been neglected for 25 years, were not ordered installed until two weeks before the fire. Previous fire inspections, if any, failed to note the need of them.

This tragedy is a repetition of others that have occurred in the past under very similar conditions, and there is little in the way of comment or conclusion that has not already been expressed. Obviously it is a condition that should not be allowed to exist, but one with which all cities have to contend. It is not simply a matter of making these places fire safe. Upper floors of old obsolete buildings with a rental value that hardly meets taxes cannot stand the cost load of structural improvement that would make them fully fire safe. The alternative of closing them is a harsh measure that city councils will not consider, and they do serve a purpose in providing indoor shelter at a minimum price for unfortunates who would otherwise resort to hovels on the river banks or under viaducts.

As long as we are to have cheap lodgings in the upper floors of old buildings, it would be better to have proper regulations that the occupant can follow under official supervision than structural requirements that the owner cannot and will not meet. Good fire prevention practice does not require that we insist on making old buildings into new ones or that modern specifications be fitted into old settings. But that is about the substance of all proposed ordinances regulating the use of old buildings. Owners and contractors fight them as impracticable, and city departments "pass the buck" to the council, where the matter dies by default and we get no regulation at all.

It is possible to have adequate rooming house regulations without undue hardship to owner or occupant; to control the number of inmates and the manner of housing in relation to the area and exit facilities, and with good housekeeping conditions. It should not demand fireproofing of ceilings, partitions, stair enclosures and other impracticable measures that prevent adoption of codes for this purpose. But it would prevent the installation of additional combustible material, and overcrowded conditions as in this instance. Even under these worst conditions more than half the inmates reached safety; under any reasonable restriction there would be no occasion for loss of life even in an old building. To avoid one such tragedy it would be a profitable investment for any city to set up a special rooming house inspection department, with adequate regulations and frequent follow-up inspections to assure the end of these slaughter pens.

Fire Protection in Relocation Centers.

By William E. Hoffman,
Fire Protection Adviser, War Relocation Authority.

Fire protection in time of war presents many difficulties and complications which are not found in peacetime. Some of these spring from the shortage of materials, while others are traceable to overcrowded housing and other problems that have grown out of the wartime situation. Making a strong bid for top honors in complexity are the fire control problems found in the ten relocation centers where the people of Japanese ancestry, evacuated from the Pacific Coast last year, now live under supervision of the War Relocation Authority. In spite of difficulties, the record of fire losses over a period averaging about one year for each center, is calculated to be only about 25 cents per capita. Vigilance on the part of the fire crews and co-operation of the relocation center residents are credited by the WRA fire protection officials for this low loss record.

Since ten centers are all located in remote places, it is impossible to obtain assistance from outside communities. Many of the centers are in desert or semi-arid country, where low humidity, high temperatures and high wind velocity combine to present an extreme fire hazard.

In order to understand the fire protection problem faced by the WRA, it is necessary to know something of the conditions leading up to the establishment of the relocation centers. There were approximately 110,000 of these people of Japanese ancestry who were moved by the Army first to assembly centers under control of the Army, then to the relocation centers administered by the WRA. As accommodations at the assembly centers were rather makeshift and temporary, the work of selecting the sites for the relocation centers and of constructing living quarters for these people was of necessity hurried. Lack of time and inability to get all of the needed materials made it necessary to omit many features of construction which would have lessened the fire hazard. To further complicate the situation, the pressing need to move these people from the assembly centers resulted in the arrival of thousands of people at the relocation centers before the construction was fully completed. At the Colorado River Center in Poston, Arizona, some 11,000 people were moved in before a single piece of fire fighting equipment was received. An adequate supply of fire fighting equipment has not yet been received at all of the projects.

Among the 110,000 people who were moved from their homes on the West Coast, only three men were found who had had any previous fire department experience. It was necessary immediately to launch training programs at all of the centers. Due to the shortage of equipment, men and women were

This crew of women fire fighters at the Minidoka Relocation Center temporarily replaces men who are called away to harvest crops.

trained in the use of shovels and sand, and other rudimentary fire-fighting practices. Volunteer brigades were organized in addition to those who served on the regular shifts of the fire department.

As the War Relocation Authority set up a program whereby individual residents were permitted to volunteer for seasonal work on farms and many of those who had received fire protection training left the centers, it was necessary to recruit and train replacements. Last fall the peak of this seasonal employment was reached when nearly 10,000 workers from the assembly and relocation centers were out helping to harvest the sugar beet crop. At the Minidoka Center, in southern Idaho, so many men had left for harvest work that one of the fire stations was left without any personnel. A staff of women was installed to take the place of the men. As far as it is known, this is the first crew of women fire fighters organized in the United States. The women were drilled by qualified fire protection officers and, from all reports, did an excellent job. They drove the fire engine, laid hose lines, connected hydrants and pumpers, and ran the pumps. They responded to fires, but the off-duty firemen from the other center station were usually present to assist in handling the nozzles in case they were needed. Some of these women fire fighters were retained as inspectors after the men returned from the beet fields.

At all centers communication facilities have been very limited and inability to get materials has delayed installation of adequate systems. To meet this

This young evacuee thoroughly enjoys manning the nozzle end of a fire hose as he helps flood a skating rink at the Heart Mountain Relocation Center.

situation, a system of runners was set up and is in partial use at some of the centers even today.

Administration of the fire prevention program in the War Relocation Authority is placed in a separate section under the assistant Project Director in charge of operations. In Washington there is a fire prevention officer who directs the section and makes regular check-ups at all centers. At each project there is one Civil Service fire protection officer with one or more assistants. The fire department at each center is headed by an evacuee fire chief with assistants, and a corps of officers and firemen under his direction. A regular staff of inspectors, all evacuees, have been trained and volunteer brigades supplement this force when threatening fires occur.

The very type of construction and flammability of the buildings makes the task of fire protection difficult. The buildings are of the temporary barrack type, such as are used by the Army for field operations. Most of them are 20 ft. by 100 or 120 ft., frame, covered with tar paper on the sides and roof. At the Gila River Relocation Center the construction is somewhat different

Quick work by the evacuee fire department kept this fire at the Tule Lake Center hog farm from doing more than minor damage.

from that at the other projects. The barracks at Gila are frame, sided with painted gypsum board, and unlined.

The barracks at all of the centers are set in rows or blocks 50 ft. apart, and the blocks are separated by 200 ft. wide fire-breaks. Incidentally, many of these fire-breaks have been planted by the evacuees to victory gardens.

In the training of the fire prevention staff at all of these relocation centers the approved texts of the National Fire Protection Association have been used. In all new construction which has been undertaken at the centers by the War Relocation Authority, and in all alteration and repair work, the N.F.P.A. codes have been followed. In some cases this has delayed badly needed housing and school construction because of difficulties in getting materials, but it is felt that adherence to these requirements has lessened the fire hazard.

Fire hazard is not alone a matter of construction, as the natural setting in which the centers are located seriously complicates the situation. The annual rainfall at seven of the ten centers is less than 10 inches. Two of the centers, Manzanar in the lower Owens River Valley in California, and the Colorado River Project in western Arizona, about 20 miles from the town of Parker, are in sections known to be among the driest in the United States. The United States Weather Bureau reports that humidity readings of less than ten per cent

A truck company of the Heart Mountain Fire Department sets off on a practice run.

can be expected on the average of 12 days during the summer and early autumn at Manzanar. Readings taken at Independence, California, six miles from the project, have gone as low as 2½ per cent. The same meteorological conditions which produce periods of low humidity are conducive to strong winds at Manzanar, and the two are likely to occur simultaneously during periods of high temperatures. The Weather Bureau has officially recorded a wind velocity of 100 miles an hour at Independence, with velocities above 45 miles an hour in all months of the year, and 50 miles an hour in nine months. These are the highest wind velocities recorded by any Weather Bureau station in California.

Humidity conditions on the average are not quite so severe in the lower Colorado River Valley as they are at Manzanar. The temperatures, however, range somewhat higher and the fire hazard is just about as severe. Water surface evaporation amounts to about 130 inches a year, or more than 30 times the annual rainfall. This center is also subject to high winds, at times more than 40 miles an hour and infrequently as high as 60 miles an hour.

High temperatures and low humidity are also unfavorable factors at the Gila River Center, which is located about 50 miles from Phoenix.

At one of the more northern centers, the Tule Lake Project in northern California, general climatic conditions constitute only a slightly less acute fire

hazard. Humidity conditions of between 10 and 15 per cent are common, and on four to six days annually the relative humidity reading may be expected to fall below 10 per cent. These periods of low humidity are usually associated with high temperatures and considerable wind movement. While there is no anemometer at the Tule Lake village co-operative weather reporting station, near the project, the Klamath Falls, Oregon, station, about 40 miles away, has often recorded winds in excess of 40 miles an hour. In May, 1942, a velocity of 64 miles an hour was recorded at Klamath Falls, and there is good reason to believe that even stronger winds occur in the Tule Lake basin.

Low temperatures, causing freezing of water pipes and other attendant dangers, are among the elements that must be overcome at some of the other centers. The Central Utah Project, the Minidoka Center in south-central Idaho, and Heart Mountain Center in northwest Wyoming are those where low temperatures occur.

While it is hardly possible to compare a relocation center with the ordinary American city of the same population, some comparison can be made. Many of the centers are intended for a total population of 10,000. The water supply for fire and domestic use in the usual American city of 10,000 population, with adequate building and fire regulations, is set up on the basis of 250 gallons per capita per day, or a total flow of 8000 gallons per minute. In a relocation center designed for the same population, but with much more limited storage facilities, the set-up is on the basis of 100 gallons of water per person per day, or a total flow of 2900 gallons per minute. Water consumption at the centers has been in excess of 100 gallons per capita per day. In addition, the fire flow is largely dependent on pumps that operate on a single source of power. Some standby pumps have been installed, but their capacity is not sufficient to provide adequate fire flow. The accompanying table sets forth the recommended minimum requirements:

Table I. Recommended Minimum Fire and Domestic Water Requirements for WRA Projects.

	WATER REQUIREMENTS							FIRE ENGINES		
									Number of Pumpers	
Population	Gal. Allowed per Cap. per Day	Per Cap. GPM	Fire Flow GPM	Total Flow GPM	Residual Pressure PSI	Storage Needed M Gal.	Hours Reserve Required	Pumping Cap. GPM	On Duty	†In Reserve
5,000	100	700	1,000	1,700	20	204	2	1,000	1	1
8,000	100	1,120	1,000	2,120	20	254	2	1,250	2	1
10,000	100	1,400	1,500	2,900	20	522	3	1,500	2	1
15,000	100	2,100	2,000	4,100	20	984	4	2,000	3	2
20,000	100	2,800	2,500	5,300	20	1,590	5	3,000	4	3

†No pumping engines are in reserve at any project.

The enthusiastic co-operation shown by the evacuee people has been largely responsible for the excellent fire protection record which has been achieved. In addition to the continual training program, the regular inspections which are made, and the volunteer fire brigades which have been organized at all centers, a bureau of public relations is in operation at each. The purpose of this bureau is to organize the residents of each block, conduct fire drills in the schools and hospitals (among the staff personnel), and to give talks before various assemblies, including schools and churches, in an effort to make the residents fire conscious. Duties are assigned to each resident in case of fire. The bureau also directs the Boy Scouts in fire prevention activities.

The following table shows the fire record at each of the relocation centers:

Table II. WRA Fire Losses from Inception of Project* to June 15, 1943.

Project	Number of Fires	Fire Loss	Per Capita Loss
Central Utah	27	$480.00	$.048
Colorado River	45	13,700.00	.685
Gila River	2	25.00	.002
Granada	43	497.00	.063
Heart Mountain	12	3,840.00	.384
Jerome	5	250.00	.025
Manzanar	15	125.00	.013
Minidoka	6	105.00	.01
Rohwer	1	12.00	.001
Tule Lake	64	5,860.00	.397
Totals	220	$24,894.00	$.25

NOTE: These figures are based on reports sent to the Washington Office by the various Projects.

*Some projects have operated for periods of more than a year and others for less than a year.

Town Planning Lessons of the Fire Blitz.

By Eric L. Bird, M.C., A.R.I.B.A.

There could hardly be a less suitable time than the middle of this war at which to discuss frankly the relationship between town planning and air attack. Air attack has two dominant factors; the first consists of the potential performances of aircraft and of bombs; the other, of the natures, locations and densities of target areas—that is to say, of town planning in its widest sense. These two factors have been subjected to intense study by expert staffs, on both sides, during the last three and a half years. Either side would be delighted to obtain from the other a summary of information on the natures, locations and densities of target areas and on the methods by which the vulnerability of these areas can be assessed. Therefore I have to restrict discussion to matters that have either become common knowledge or are beyond the control of the enemy. Further, the opinions expressed are my own and should not be regarded as officially accepted.

Cities and towns are very vulnerable to incendiary attack. This is the same thing as saying that they burn very easily—a condition that is much the same in war as in peace. There is more fire damage in war than in peace merely because the enemy sets the town alight in several places at once, whereas in peacetime it is commonly ignited by accident in only one place at a time.

The risk of fire is inherent in buildings occupied by man. Most of the things he uses are combustible or can be made useless by heat. Nearly all food is combustible, together with the packing cases, cartons, paper, etc., used to contain it. Textiles such as clothing and furnishings also are combustible. Almost all buildings contain large quantities of dry timber in their construction, equipment and furniture. Many industrial occupancies, though not all, are serious fire risks, while a few are by their nature extremely hazardous. The typical built-up area may be regarded as so many acres of combustible material, disposed in open stacks so that it can burn freely.

Towns are live organisms, the bodies of which change and develop through the centuries. Town-development has two important features: first, the rate of change is irregular; they may grow comparatively slowly or they may double in size in a decade or two, according to local fluctuations in industry and trade; the buildings—which may be regarded as the unit cells of the body corporate—may be replaced either at short or long intervals according to the rate of growth and the relative prosperity of the town. Secondly, the form and growth

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of towns have been in the past mainly a matter of chance, though here and there showing traces of primitive ideas in town planning, while the buildings have been expressions of current social ideas, executed in those building materials that have been obtainable locally. Within the last century some degree of public control of structural design has been introduced and, within the last decade, of town planning. But these newer controls have as yet had but small effect on the great masses of urban development. Therefore our chief concern is with the town as it exists today, or rather as the Germans found it when they began bombing in 1940.

Today we are in the early stages of an era of positive town planning, under which layout and growth of towns will be much more strictly controlled than heretofore. Also, design of building structures is now likely to be subjected to fairly close scientific control in such matters as stability, hygiene, provision of light and air and fire protection.* So far as incendiary bombing is concerned, the lessons we seek and our objectives for the future can be summarized in one sentence, namely: "Towns must be planned and built so that they are less vulnerable to fire than in the past." Whatever we do must be begun now, because on the outbreak of any future war, the target will be what we have made it during the intervening years of peace.

It is obvious that susceptibility to fire is not uniform throughout a town. The more serious fire hazards in the form of shops, warehouses and certain industrial processes, tend to congregate into groups. They do so for various reasons, such as the convenience of the population in shopping, access to rail and water transport and the inevitable grouping with major industries of the subsidiary industries that feed them. Such grouping is essential to the peacetime efficiency of an urban community and is therefore unavoidable. We cannot go in for a system of widespread dispersal without incurring a serious reduction in peacetime efficiency. These commercial and industrial groups have a fire-susceptibility that is in strong contrast to the purely residential areas.† They have suffered far more from incendiary attack than have groups of dwellings, even where the density of incendiary bombing has been equal on both types of area.

The fire-susceptibility of an area depends in the first place on the average fire-susceptibility of the unit buildings composing it. If we consider together the occupancy and structure of each building, we can classify it either as a high, medium or low fire risk. Considering a typical central area as a whole,

*British cities generally do not have buildings codes as we know them in the U. S. and Canada. An exception is a set of building laws enforced by the London County Council. —Ed.

†British residential areas are uniformly buildings with brick walls. Residences in rows are separated from each other by solid brick walls. Wooden walls, wooden siding and wooden shingles are practically non-existent.—Ed.

we find that from 80 to 90 per cent of its buildings are high or medium risks. This contrasts strongly with the predominantly low fire risks of houses in residential areas.

In an area consisting chiefly of high fire risk buildings, incendiary bombs will create uncontrollable fires more quickly than in areas where such buildings form a small proportion of the total. When fires have grown so that they fill whole buildings, the large bodies of heat thus created can more readily ignite adjacent buildings than is the case in an area of low fire risk buildings. Thus the conflagration comes into being—the great mass of burning buildings from which fire advances almost irresistibly through stack after stack of fuel provided by still more buildings.

A glance at the plan of a typical town center shows it to consist of groups of properties called blocks (see Fig. 1). It is the risk of the block that I now want especially to consider. The nature of a block changes over a period of years as the town develops. The rate of change in the individual block depends on its distance from the center of the town; the outer blocks remain purely residential over long periods, while those nearer the center tend to change to commercial occupancies. The block may remain static for centuries or it may change its nature in a few decades. Usually it begins by being chiefly residential. As the town grows, houses are converted to shops, which extend outwards over the front and back gardens. Some buildings are wholly rebuilt. The back land is taken up by factories and storage buildings. Thus not only are high fire risk occupancies introduced, but more of the ground is covered by buildings which, in terms of incendiary bombing, means that a higher proportion of bombs in a salvo will score direct hits on buildings. At the same time, the greater amounts of combustible materials represented by the commercial occupancies will cause any fires to grow rapidly to uncontrollable dimensions. Further, the close spacing of buildings within the block now greatly increases the risk of fire spreading from building to building.

As site values rise, the houses are demolished to make room for extensions of the shops and factories, rights of light* being acquired by purchase. More land is built over, higher buildings are erected and the occupancies become almost entirely high fire risk. Not only are the fire hazard and the conflagration hazard of the block now very great, but the difficulties of access by firemen to the interior of the block are acute, which increases still more the chance of the block being totally destroyed by conflagration.

A fourth stage is reached in the larger cities, where site values have become very high. The blocks tend to come into the ownership of a few concerns, who erect large department stores, hotels, factories, blocks of lettable offices,

*In Great Britain the property laws prevent a building owner providing windows in any wall that abuts on the boundary between his property and another unless he negotiates an "easement" for this purpose with the adjoining owner.

etc. The fire risk now tends to become somewhat less, partly because insurance rates make profitable the employment of fire-resisting construction and the installation of sprinklers, and partly because firemen can now more readily attack fires inside the buildings. Some local authorities, notably the London County Council, have, in the past, required the employment of fire-resisting construction and sprinklers in new commercial buildings, but the great majority have not. There are occasionally to be seen examples of a fifth stage, where the whole block has been redeveloped as a single building.

It is perhaps more profitable to examine in detail an actual block as it exists today. The following data are derived from such a study of a block located in the center of a town of 90,000 inhabitants. The town is essentially a modern one; its traces of medieval planning and building are very slight and its principal growth has occurred in the last fifty to 100 years. Its industries are mixed and mostly of the class termed "light."

The block is 2.6 acres in extent; one side fronts on the main street containing the principal public buildings and shops (see Fig. 2). It has 72 per cent of its site area covered with buildings. If the streets are included, the neighborhood of the block is found to be 63 per cent built up. This is in strong contrast to development at twelve houses to the acre, where not more than 15 per cent of the land is covered with buildings.

An examination of the occupancies (see Fig. 3) shows that most of them are commercial or industrial. They have extended into the center of the block, usually in one- or two-story structures of varying height, and of construction ranging from good to shoddy, the latter predominating. These back extensions are commonly not only sheds of timber construction, but also contain the reserve stocks of the shops. These stocks are frequently highly combustible. One such shed in this block was found to contain 10 tons of soap stacked solid to the roof. The principal shops front on the main street; in the side streets the shops are mostly on the ground floor only, with offices over; there are several small factories or workrooms and only one dwelling.

This leads inevitably to a study of the overall fire-susceptibility of the block (see Fig. 4). The shops and their storage buildings in any case are hazardous in respect of fire. It happens also that an unusual proportion of the local industries is hazardous. Thus this block is not quite typical of towns in general, because its fire-susceptibility is a little above average—but not very much so.

What is to prevent the spread of a conflagration through this block, apart from the activities of the fire guards and the National Fire Service* (see Fig. 5)? There are no fire breaks at all in the form of open spaces within the block, and three of the four streets bounding the block are too narrow to prevent the

*The public fire department. Since May, 1942, all public fire departments in England and Wales have been merged into one organization under the direction of the Home Office.

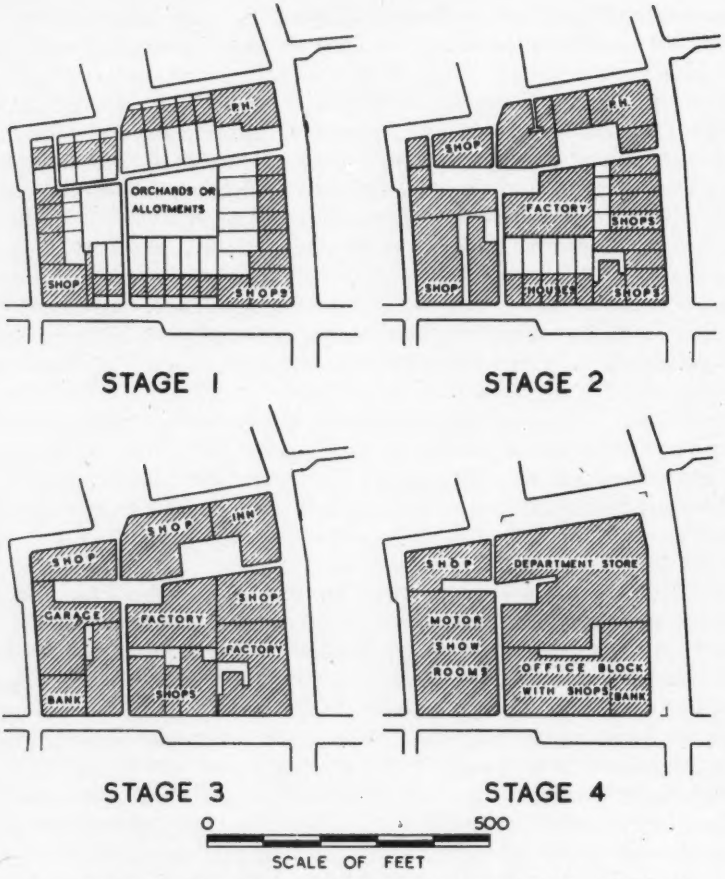


Fig. 1.—Four stages in the development of a typical building block.

spread of fire to adjacent blocks. We must therefore look mainly to the stopping or delaying action of the party walls between buildings and of any division walls that may exist inside buildings. A true fire wall is one that prevents the passing of fire either through or over it, for which purpose it has to be of solid brickwork or reinforced concrete and to extend at least 3 ft. above any combustible roof. We find such fire walls to be very few in number and that none extends wholly across the block, so that fire can outflank them all. It is true that solid party walls that do not extend above the roof tend to lessen the task of the National Fire Service, who can restrict the spread of fire by

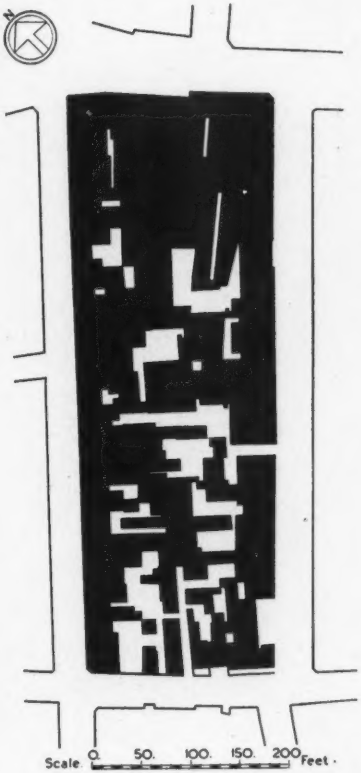


Fig. 2. Analysis of a building block: the extent of the ground covered with building.

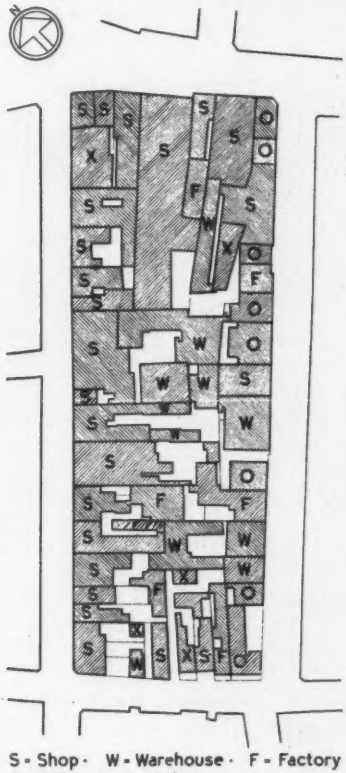


Fig. 3. Analysis of a building block: the occupancies and properties.

hose streams on the roofs. This is fairly easy from the streets, but very difficult from the congested courtyards. Further, because building owners have from time to time acquired rights of light over adjacent properties within the center of the block, the windows so provided form a ready path for fire to travel from building to building, still further nullifying the value of the fire walls and party walls.

Herein undoubtedly lies the reason why town centers, as they have grown up through the centuries, are so fire-hazardous. In the course of time, a num-

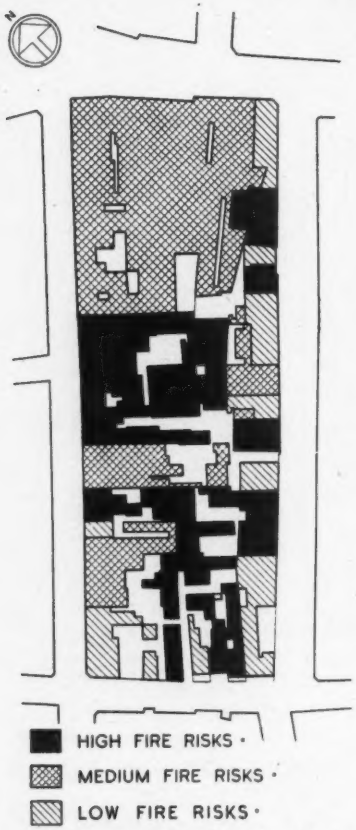


Fig. 4. Analysis of a building block: distribution of fire risks.

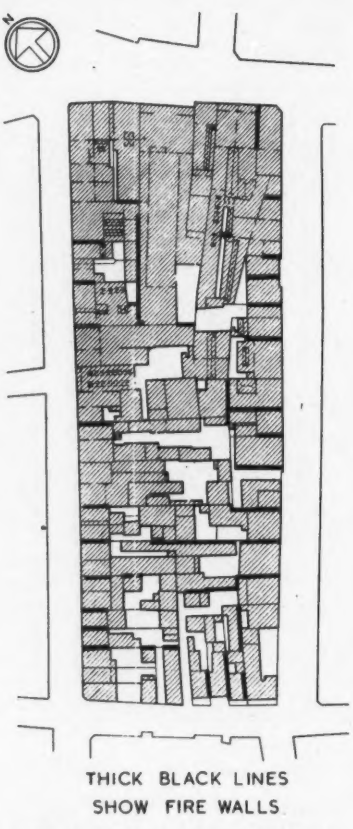
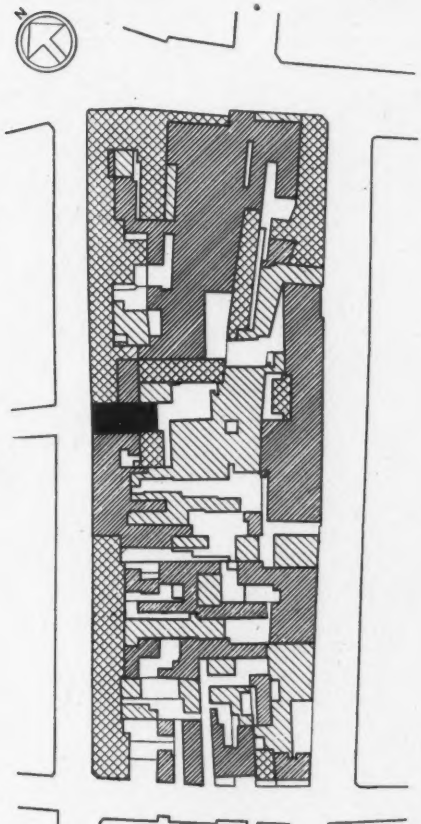


Fig. 5. Analysis of a building block: distribution of fire walls.

ber of small fire risks, each fairly well isolated from the others by more or less fire-resistant party walls, have become converted into a single high fire risk, partly because of the introduction of hazardous occupancies, but chiefly because building in the centers of blocks has not been controlled.

We are all accustomed to looking at towns from the streets, and this gives a misleading impression of the real nature of the blocks of building. Inspection from the street also gives a wrong idea of height and also of the quality of construction of the buildings. Let us proceed to consider these two points.

Taking that portion of the site that is covered with building (see Fig. 6), we find that 28 per cent is single-story, 41 per cent two-story, 29 per cent three-story and 2 per cent four-story. Although the site area is 113,250 sq. ft.



Area of Block 2·6 acres = 113,250 sq. ft
Covered with Building = 72%

DEVELOPMENT	PER CENT
4 Storey	2
3 do	29
2 do	41
1 do	28

Total of floor area in all buildings = 180,000 sq. ft.

Fig. 6. Analysis of a building block: height of buildings.

in extent, it carries no more than 180,000 sq. ft. of floor area (excluding a few basements). Obviously, this is an exceedingly wasteful use of land, quite apart from the fact that the block is an almost perfect incendiary target. It is also worth noting that the area on which this block stands had an acute car-parking problem before the war and that many of the rooms on the ground floors are ill-lit and poorly ventilated.

Assuming we were given the task of rebuilding this block as a whole, providing the same total of floor area as at present—namely, 180,000 sq. ft.—we find that if we built it in three-story structures, we would cover only 53 per cent of the site as against 72 per cent at present; if in four-story structures, 39 per cent and, if in five-story, 31 per cent. It is true that many of the activities must be on a ground floor, but there are several now at that level that could be transferred one or two stories up without harm to them and with benefit to other owners.

The block here studied is exactly typical of the great majority of towns as existing today. Exceptions can, of course, be found in the hearts of a few cities where very high land values have made tall buildings profitable; but even these exceptional blocks are surrounded by a ring of lower blocks very similar to the one we have examined in detail.

Study of the actual structure of buildings as they exist in town centers has revealed that many buildings are not what they appear to be. Many towns are of medieval foundation. In these not only do the street lines follow the medieval town plan, but a quite surprising number of the buildings are actually of medieval construction, that is to say largely of timber. This means that many of the party walls are not of solid brickwork or that they have been patched, raised or otherwise altered with all sorts of construction. These patched party walls frequently contain bonding timbers which either transmit fire through the wall or, in burning away, cause it to collapse. Many buildings in these old town centers that present to the street imposing façades, ostensibly of solid brickwork, are in fact concealed medieval structures. A study of these buildings reveals their histories. A typical example appears to have begun life in the Middle Ages as the dwelling of a merchant, having a vaulted cellar below ground for the storage of goods and a timber-framed structure above, infilled with wattle and daub.* In the sixteenth century the house was rebuilt, in the same type of construction, but probably with the timber frame infilled with brick. In the eighteenth century the front was remodeled either by lath and plaster over the front or by the construction of a brick façade wall in front of the timber frame. In the nineteenth century a shop front was inserted and a back addition added. Finally, as the building became wholly used for commercial purposes, a steel portal frame was inserted and a warehouse or workroom attached at the rear.

*Stud and mud.—Ed.

Towns built mainly in the nineneenth century naturally do not have timber-framed walls, but the timber floor and roof is practically universal, and the brickwork—constructed in what was literally the golden age of the speculative builder—is frequently very shoddy. Fire-resisting construction is far more rare than most people suppose. In one city of 80,000 inhabitants, there are only six buildings that can be regarded as fire-resisting by modern standards, as, for instance, those now enforced by the London City Council for certain classes of building. Study of burnt-out areas immediately after fire blitzes has shown—even in large cities—only occasional fire-resisting buildings still standing, and these have often been gutted by fire entering at windows.

It may be said that I have dealt rather more with building construction than with town planning. Although from the point of view of public administration they are regarded as separate entities, they are in fact a single interlocked subject. Together they control the actual physical form of the town in all aspects, of which fire-susceptibility is one of several.

So far as Civil Defence is concerned, the basic aim can be simply stated as follows: The Atlantic Charter envisages preparation for a future war. Although the devastation hitherto caused by incendiary attack in central urban areas is small when the total extent of such areas is considered, incendiary attack has become established as the most effective means of destroying them; we may expect it to be far more severe in a future war than in the present one. As towns have at present grown up they are uncomfortably vulnerable to incendiary attack, therefore we should so control their plans and structures that they are much less vulnerable.

The main principles are as follows: First, town planning, so far as primary layout is concerned, can and should provide streets that are wide enough to form fire breaks between blocks. This means that streets should be at least 60 ft. wide and preferably about 120 ft. wide. The average width in most town centers is at present nearer 40 ft. than 60 ft. In this country we have become so accustomed to narrow streets that we do not realize their narrowness. In Moscow hardly any streets are of less width than 60 ft. and most are more than 100 ft. Secondly the block itself should be subdivided into what are termed "fire cells" by means of fire walls, thus preventing the spread of fire within the block. Thirdly, the buildings themselves in central areas should be of fire-resisting construction and if exceptionally large, be sub-divided into fire cells. Finally, there should be very strict control of extensions, particularly in the centers of blocks: the haphazard purchase of rights of light over adjoining properties should not be allowed; no building owner should be permitted to create a hazard to himself, to his neighbors and to the nation at large merely by paying for it.

The root of the problem lies in the existing system of land tenure. Because blocks usually consist of several freeholds, each freehold can be developed

independently of others, or owners can purchase pieces of back land from neighbors. Where the land is leasehold and all leases fall in together, the block can be redeveloped as a whole. For many years past the municipality of Stockholm has been buying land with this aim of wholesale periodic re-development in view; this power of large-scale re-development has long been coveted by all town planners; for it to be effective land must be owned or controlled in large units, either by the State, municipalities, corporations or individuals, but it can only be effective if governed by a far-seeing policy and powerful control.

But the lessons to be learned from fire blitzes are clearly not limited to possible future wars. Even if we never have another war, it cannot be denied that fire blitzes have shown us how shoddy, how inconvenient, how unhealthy, how unworthy are the centers of large towns. If we have learned this lesson and profit by it, future generations may even look back on this time and talk of the benefits conferred on civilization by the bombing aircraft! The aim of providing greater protection against incendiary attack accords very well with the aims of providing light, air, traffic space and amenity. Further, the measures here discussed will greatly reduce fire losses in peacetime.

Finally, the evils revealed by the blitz are directly attributable to lack of adequate control of building in the past, especially in provincial towns. It seems clear that something like a National Code of Building, universally applied, is necessary both as an essential component of Civil Defence and, at the same time, to fulfill the peacetime aims I have just mentioned. Local authorities should not be allowed to have any building regulations in respect of fire that they choose or, as was frequently the case in the past, none at all. The bombing aircraft is no respecter of local autonomy.

Treatment of Burns.

By Charles C. Lund, M.D.,
Assistant Professor of Surgery, Harvard Medical School;
Visiting Surgeon, Boston City Hospital.

For about ten years most doctors have been preaching that ointments must never be used as a first aid treatment of burns, but that tannic acid solution, either pure or improvised in the form of tea, should be applied at once. If these were not available, saline or soda solutions were to be used. The reason for avoiding ointments was that they had to be removed before any escharotic* treatment could be used. Now the British Army in the Middle East has forbidden the use of tannic acid either as first aid or as definitive treatment, and more and more individuals and organizations are advising simple ointments for first aid and for definitive treatment. What has led to this extraordinary change of thought?

The escharotic treatments were introduced in the first place to reduce the degree of shock and the severity of infections. Shock was reduced by reduced surface weeping and infection influenced by antibacterial activity of some of the components of the eschar. Since the advent of plasma to replace that lost from the blood stream, and the use of pressure dressings and plaster casts in the surface treatment, the use of escharotics to reduce shock has become less important. More critical evaluation of cases has shown that even the lessening of infection by escharotic treatments is not achieved in severe cases, and particularly if infection is locked in by tanning an uncleaned burn wound as often occurs under first aid conditions. In addition, some of the escharotics, for example, tannic acid and triple dye, delay the healing of small wounds and burns, and some of them, such as tannic acid and picric acid, may poison certain patients with large burns. For these reasons the best recommendation for first aid that can be now made is some simple bland ointment, such as plain petrolatum or boric acid ointment. If these are not available, apply a dressing of saline or weak sodium bicarbonate solution and keep it moist.

Note by Editor: Great progress has been made during the past year in burn therapy, resulting in revolutionary changes in first aid and definitive treatments. Our attention was focused on this last July when the Office of Civilian Defense withdrew its recommendation of the tannic acid treatment and urged the use of sterile boric acid ointment or petrolatum. We approached Dr. Lund, recognized authority on the treatment of burns, for an explanation of this seeming inconsistency. Through his courtesy we are permitted to publish this abstract of an up-to-the-minute article entitled "Burns" which appears currently in the Rhode Island State Medical Journal. Readers interested in further reference material are referred to the original article, which contains a complete bibliography.

*Escharotic treatments are those which form a crust or eschar over the burned area as, for example, the tannic acid treatment.

Definitive Treatment of Minor Burns.

For the purposes of this discussion, minor burns are defined as burns of small area (not over 5% of surface area) and of only part of the thickness of the skin. McClure has recently pointed out the chaotic conditions prevailing in the treatment of minor burns in the various clinics of certain large industrial concerns. He urges the use of simple boric acid ointment, well and firmly bandaged and not changed too frequently. This is good advice because there are four major requirements for the successful treatment of such burns, and this program meets all four of them. These requirements are relief of pain, prevention of infection, optimum conditions for rapid healing, and minimum disability during and after treatment.

Pain is absent under either a pressure dressing such as is recommended by Allen and Koch or under a plaster cast as recommended by Levenson and Lund. To do a pressure dressing properly takes a little planning and a surprising amount of practice. However, once a suitable dressing has been applied it should not be removed from a part thickness burn until the burn is healed. As pain in a burn is caused only by friction or by changing the dressing, it is seen that following this program will eliminate practically all of it.

Infection can get into a burn only when the burn is uncovered or inadequately covered. Cope has shown that even in major burns the contamination present at the time of arrival at a hospital is not a particularly serious matter in most cases, and that burns treated with no attempt to wash the surface do as well as burns that are washed. The dangers in washing a burn are that the washing may be inadequate or, when adequate, may be damaging to the tissues. Levenson and Lund, Logie, and Trueta, have also shown that burns encased in plaster will take care of the infection that is on the surface, while Willits and Hare show the ease and frequency with which burns and wounds become infected at changes of dressings. For these reasons a treatment to be safe from the standpoint of infection must be one in which dressings are not changed until healing has occurred.

Optimum conditions for healing are not created by escharotics, by antiseptics, by "shot gun" ointments or by nutritive ointments. Cells can only grow under certain conditions of moisture, temperature, pH, concentration of salts, etc., comparable to those prevailing in tissue fluid. These can only be created on the surface of the body by the tissue fluids themselves and therefore only when a stable covering is provided.

Minimum disability during healing can be provided in several ways. For instance, infrequent visits to the doctor save much time for the ambulatory patient to work. A dressing, if possible, should not be too bulky, but it must be bulky enough and firm enough to splint the part sufficiently to avoid all friction and bulky enough to avoid soiling from the natural discharge of the burn. Levenson and Lund, who were stimulated to study this aspect of burns

by the very important animal experiments of Glenn, Gilbert, and Drinker, believe that in certain burns of the hand the prevention of swelling by a plaster cast prevents formation of abnormal deposits of fibroblasts in the tissues, and that hands treated in this way have returned to normal function more rapidly than hands treated by other methods.

Major Burns.

The principles underlying the treatment of major burns (all burns larger or deeper than second degree burns of under 5% of body area) are well stated by Whipple. The problems of treatment of the surface are complicated by the very severe systemic effects of these burns that must be treated prior to or at the same time that the burn is treated. As Pack and Davis have said: "It is wise counsel to advise the immediate general treatment of the patient rather than the burned area. It is penny wise and pound foolish to consume invaluable time in applying perfect local dressings while the patient is sinking into irrecoverable shock." To treat a major burn takes planning and teamwork. Excellent directions for such teamwork have been described by Gurd and by Harkins.

Shock.

The main reliance in the treatment of burn shock should be plasma. Electrolyte should be used only to alkalize the urine or to make up definite deficiencies in electrolyte that are due to known losses. Morphine should be given rather cautiously for pain, and heat should be used more cautiously than it has been used in the past. Although Blalock made definite estimates of the great loss of plasma from the circulation into the local tissues in severe burns over ten years ago, it was only since plasma became available that it was found that some cases can lose twice their original plasma volume in this way during the first twenty-four hours if they are kept alive by giving sufficient plasma rapidly enough. Because of this loss, plasma should be given early and freely. There are two guides to dosage. One is by using a "surface area" formula, which gives a fair estimate of the requirements during the first twenty-four hours. The other is by a hemoconcentration formula, which gives values that indicate immediate needs. One "surface area" formula is to give 100 cc. of undiluted plasma for each 1% of area involved above 5%. Another formula is to give 50 cc. of plasma for each 1% of area. Hemoglobin and hematocrit determinations should be started at once and repeated every two hours. The blood pressure should be determined at least hourly. In general, hemoconcentration precedes a low blood pressure, but if the blood pressure is low, at least 500 cc. and probably 1000 cc. of plasma is needed at once. To use the hemoglobin or hematocrit as a guide, several complicated formulas have been recommended. Harkins' simple formula is, however, the most practical and useful. It is to give 100 cc. of plasma for each point the hematocrit is above

45, or 50 cc. for each point the hemoglobin is above 100. When using this formula, it must be remembered that it indicates only immediate needs. If plasma loss continues, later determinations may indicate additional amounts. In desperately shocked patients, the ordinary gravity administration of plasma does not allow rapid enough administration, and plasma may need to be given through a large needle under pressure. Some cases are burned very severely at all the usual sites for vein puncture. In such cases it will frequently be possible to administer plasma by femoral vein puncture, a technique that should be better known. In any case, the treatment of burn shock needs a considerable degree of clinical judgment, as other factors enter into the picture besides purely the surface area involved and the degree of hemoconcentration. Some feeble patients apparently have no capacity to concentrate their blood. There is also a variation in the plasma loss according to the area burned, its location and depth. In so far as possible, the plasma needs of a patient should be anticipated so as to prevent shock rather than treat it.

Early and Late Complications of Burns.

The earliest complication of burns is hemolysis of red blood cells and hemoglobinuria. It occurs only with severe burns. Patients with such burns should be catheterized at once and hemoglobin sought in the urine. Also the first blood specimen taken for hematocrit determinations should be used to test for hemoglobinemia. If either hemoglobinemia or hemoglobinuria are present, the patient should be alkalinized with intravenous injections of 40 cc. of 10% lactate to each 500 cc. of plasma or an equivalent amount of sodium bicarbonate. As soon as an alkaline urine is established, the sodium lactate administration should be stopped. Shen and Ham have shown that the source of the hemoglobin is probably from red cells burned within the capillaries of the burned skin, but its importance is that hemoglobin may be precipitated in the kidney tubules by the usually very acid urine found in burned patients, and this may cause damage to the kidneys and lead to oliguria.

Other complications are azotemia, marked increase of nitrogen output in the urine, hypoproteinemia, and anæmia. Usually these do not start until 24 to 48 hours after the burn. There is no specific treatment for the azotemia and azoturia except to maintain fluid balance without flooding the patient with salt. One should, however, keep in mind that azotemia and azoturia indicate a real breakdown of protein tissue and this loss must be made up in the food promptly. This loss, the demand for tissue regeneration, and the loss of protein from the surface in the form of plasma and pus is so great that the available protein stores may be depleted. As a result the plasma protein level decreases to extremely low points, and the patient's weight falls off rapidly. This is a very serious circumstance that cannot be corrected by plasma or whole blood administration, and occasionally not by ordinary high protein diets because large enough quantities of protein cannot be given in this way

for long enough periods of time. The solution for this situation is forced feeding of a high protein, high vitamin diet, given preferably by stomach tube and supplemented by amino acids given through the tube or intravenously. The amounts of protein needed may exceed 300 grams (dried weight) per day or the equivalent of about four pounds of steak per day. The anæmia of burns does not respond easily to iron. Multiple whole blood transfusions are needed. In some cases as many as 25 transfusions of 500 cc. each have been given to patients within two or three months with a successful outcome, but there are others in which even multiple transfusions do not control the anæmia.

Infection and Surface Treatment.

In spite of what has been written in the past, infection is a very small problem in large second degree burns if they are treated as indicated earlier in this paper under the treatment of minor burns. But infection is universal in cases of third degree burns and always serious in large third degree burns. These should also have bulky dressings over simple ointments, and the dressings should be changed infrequently and should act as splints. Owens gets excellent results using pressure dressings without any ointment, substituting saline compresses for ointment compresses as the inner layer. This is very important because it shows the unimportance of ointment and the importance of the dressing. Leaders in the study of burns, both civilian and in the services, are rapidly giving up escharotics and turning to simple ointments for major burns, in spite of the fact that the very recently published Military Surgical Manual V contains a section on tannic acid treatment. For instance, Churchill from North Africa writes with obvious pleasure of finding simple boric ointment used at the front there.

Orr has shown that infected compound fractures encased in plaster and packed open do well. Trueta has used this treatment extensively under war conditions. Glenn, Gilbert and Drinker, and Barnes and Trueta have shown in animals that the flow of lymph from burns is greatly decreased, the blood flow remaining normal, in the experimental animal if the burn is encased in a close-fitting plaster and that healing is better than when no plaster is used. As mentioned above, Levenson and Lund have used this treatment successfully in humans. Such a plaster should be nearly skin tight, must enclose the tip of the extremity and, if possible, extend above the injury proximally, and must fit evenly. They have been applied and the patient allowed to go home and return for removal. They should not be bivalved and should remain in place for two to three weeks. In applying the plaster the burn is first covered with a layer of sterile vaseline gauze and the dressing should be put on under strict sterile operating room conditions. Then a thin layer of dry gauze is added and a nearly skin tight plaster put over this. The plaster should be just thick enough to avoid cracking later.

Chemical Prevention of Infection.

Sulfanilamide, sulfadiazine, sulfathiazol, sulfaguanidine, propamidine, and penicillin are the most recent chemicals used locally to control infection in burns. These have been powdered on, put into ointments or creams, or incorporated into sprays or into preformed films. Although good results have been claimed for each of these methods, none of them is useful unless all the other conditions of treatment are ideal, and then, in the author's opinion, they are rarely necessary. It is wise, however, to give sulfadiazine by mouth in full doses in the early period of a severe burn, but not starting before the kidneys have commenced to secrete urine. In giving the drug by mouth one can regulate the dose easily, whereas surface applications have at times resulted in definite over dosage.

Skin Grafting.

Areas of granulation should be covered with split thickness grafts in wide sheets at the earliest moment. Of course, slough has to be out of the way and the patient's general condition must be good. It was formerly thought that any infection present on the granulations would prevent successful taking of such grafts. It is now thought that the patient's condition and the technical factors of the graft are more important. There must be no hypoprotenemia, vitamin deficiency, anæmia, or marked fever. For large areas, the Padgett Dermatome is a great help in cutting the grafts. The grafts should be sewed in place and absolutely fixed under an elastic pressure dressing. A cast should usually be employed over the dressing if the graft is on an extremity.

Explosive Properties of Metal Powders.

By Hylton R. Brown,

Chairman, N.F.P.A. Committee on Dust Explosion Hazards.

In an article entitled "Dust Explosion Hazards of Powdered Metals," which was published in the July, 1941, issue of the QUARTERLY, attention was called to the scarcity of data on the factors affecting the explosibility of metal powders. It was pointed out that practical experience had demonstrated that several of the metal powders were capable of forming explosive dust clouds in air and stressed the fact that further research would be necessary to obtain information on the explosive characteristics of many of the new powdered metals and alloys before suitable methods of providing protection against such hazards could be developed. Reference was also made in the article to some of the research work then under way in the laboratories of the Bureau of Mines to determine the relative flammability of a number of metal powders being produced commercially for use in powder metallurgy and in the manufacture of certain types of munitions.

Since that time more than 50 samples of metal powders and alloys have been studied, and some of the results of the tests have been presented in a new publication of the Bureau of Mines, Report of Investigations 3722 (in press), "Inflammability and Explosibility of Metal Powders," by Irving Hartmann, John Nagy and Hylton R. Brown. This report, which contains a number of tables, curves and illustrations, describes in some detail the methods developed for determining the relative flammability and explosibility of powders or dusts, and gives the results of different types of tests. The results of further research work now under way will be released later.

The laboratory tests reported in the new publication were planned to produce as much data as possible on the explosive characteristics of the powders. Special efforts were made to obtain information on the following subjects:

1. Ignition temperature of undisturbed layers of metal powders.
2. Ignition temperature of metal dust clouds.
3. Minimum energy of sparks capable of igniting layers of metal powders.
4. Minimum energy of sparks capable of igniting metal dust clouds.
5. Minimum explosive concentrations of metal dust clouds.
6. Maximum pressure produced in metal dust explosions.
7. Rates of pressure rise during metal dust explosions.
8. Relative flammability of different metal powders.

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9. Rate and extent of moisture absorption by metal powders in atmospheres of high humidity.
10. Maximum permissible oxygen content in inert atmospheres that will prevent ignitions of metal powders.
11. Effects of carbon dioxide and nitrogen on metal powders at high temperature.

Tables included in the report have been compiled to give in comparable order the results obtained with each type of dust used in making the various determinations listed.

Particular importance is placed on laboratory data by investigators who may wish to conduct further research on the subject and by safety engineers, accident-prevention boards and insurance commissions who frequently use the results of such tests as the basis for codes and recommendations on fire and explosion prevention. On the other hand, industrial plant operators are more interested in determining the presence and extent of hazards in their plants and the practicability of suggested methods of providing the necessary protection. It is now possible to interpret for practical use some of the information available in the laboratory reports of tests made to determine the explosibility of metal powders.

Metal Powders Tested.

Information now available on the flammability of metal powders is based largely on the results of tests with fifty-three samples which included fourteen different metals and two different alloys. Different types of the same metal were tested whenever it was possible to obtain distinctive samples, because it is known that size of particle as well as the method of manufacture have important influences on the explosibility of dusts and powders. The metals and alloys used in the series of tests are listed alphabetically below.

Aluminum	Copper	Manganese	Zinc
Antimony	Iron	Silicon	Zirconium
Cadmium	Lead	Tin	Magnesium-Aluminum Alloy
Chromium	Magnesium	Titanium	Dowmetal

As many as four samples of some metal powders made by different processes were tested; and, in one instance, sixteen separate samples of the same metal, but consisting of different size particles or made by different processes, were included in the testing program. The following methods, which are described briefly below, were used in producing the powders tested:

ATOMIZATION: In this method the molten metal is fed into a stream of air or gas, or the surface of the molten metal is struck by a jet of steam, air or gas and the fine particles are carried along with the air stream to a collector. Dust particles produced by this process are small and have comparatively smooth surfaces.

CONDENSATION OF METAL VAPOR: Carbon monoxide is used to reduce vaporized metal oxide to metal vapor, which is then passed through condensers, where fine metal powder is formed. This process is used principally in the production of zinc powder.

DECOMPOSITION OF CARBONYLS: Very fine metal powders are obtained under certain conditions by decomposing at high temperatures the carbonyls produced by passing carbon monoxide over reduced sponge metal.

MILLING: This method, which includes all types of grinding in mills, crushers, pulverizers, etc., is generally used to convert the friable metals into powders, which are classified according to size by screening.

REDUCTION: In this process metal compounds (usually the oxides) are reduced to metal powder in atmospheres of carbon monoxide or hydrogen.

STAMPING: This process, sometimes included with other forms of milling, produces a fine, flat, thin flake which is particularly well adapted for use in the preparation of paints and inks. Stamp mills are fitted with hammers, which are automatically raised and dropped onto an anvil. Small pieces of scrap placed in the mill are struck heavy blows by the hammers until the metal is reduced to particles of the desired size.

Conditions Necessary for Ignition.

Ignitions and explosions of metal powder may occur under the same conditions required to produce explosions of carbonaceous dusts. Metal powder or dust in a quiescent state may be ignited by a spark or the application of sufficient heat to raise the temperature to the ignition point. If undisturbed, the powder will burn quietly, and the fire will spread at a rate depending to some extent on the availability of oxygen to complete combustion. The same sources of ignition are generally capable of starting a dust explosion; but to obtain such a reaction the powder must be scattered in the air in the proper proportion.

The ignition temperature of the metal powders while in a quiescent state was found to range from 410° to 1742° F., twelve of the group of sixteen igniting at temperatures below 932° F. The ignition temperature of many of the metal powders was well within the range reported for a group of fifteen carbonaceous dusts, 518° to 670° F. Ignition tests of this type are generally made with quantities of the dust placed on flat surfaces inside an electrically heated furnace or oven equipped with temperature control and indicating instruments. The tests are designed to show the conditions under which ignitions may occur in a plant if dust settles or is allowed to collect on hot surfaces.

Ignition of a dust cloud usually requires a higher temperature or a larger source of ignition than is necessary to cause inflammation of a quiescent layer of the same material. In the series of tests with metal powders reported in the publication now available, it was found that the temperature necessary for ignition of a dust cloud generally ranged from 599° to 1652° F. In a few cases

it was necessary to use magnesium-barium peroxide pellets to obtain ignitions in the pressure measuring apparatus. These pellets produce a short, bright flame with a temperature over 3000° F. Again, many of the temperatures are well within the range of ignition temperatures determined for carbonaceous dust clouds, and the tests show that many normal factory operations that require heat may be the source of ignition for a dust cloud.

Other tests were made to determine the possibility of igniting dust clouds and dust deposits with electric sparks. In some tests to determine the explosibility of dust clouds, a high-voltage continuous spark having an average power of 20 watts was used as the source of ignition. The minimum energy required for ignition of the dust has been determined by measuring the power of static spark discharges. It has been found possible to ignite layers of dust or powder on a metal plate with the spark discharge from a condenser charged to 400 volts, and the spark energy required for such ignitions has been found in a number of cases to be less than 0.05 joule. One dust sample was ignited by a spark having a measured energy of only 0.00024 joule. These tests indicate the extreme ease of ignition of some of the fine metal powders and call attention to the necessity of using only the special types of electrical equipment designed and approved for such locations. Grounding all apparatus to remove static charges is essential wherever there is any chance that a discharge will occur in a dusty atmosphere.

Metal powders have certain limits of explosive concentrations, and it is possible to have the mixture of powder and air too rich or too lean to support combustion. These conditions under which metal powders will explode are quite similar to the limiting factors for carbonaceous dusts and gases. For the group of metal powders that have been tested, the lower limit of explosive concentrations has ranged from 20 to 500 milligrams per liter. The figures, which are about the same as those obtained in tests with carbonaceous dusts, correspond to 20 to 500 ounces per thousand cubic feet. Some investigators have reported ignitions of both metal powders and carbonaceous dusts at much lower concentrations, and further investigation may reduce the figures cited. The fact that explosive mixtures capable of producing destructive pressure can be formed within the limits given is sufficient justification for the adoption of all possible precautions to prevent the dissemination of dust from the point of production and to remove promptly any dust accumulations that may occur through spills or leakage from machinery.

The fineness of the powder, which may be referred to as the particle size, and the uniformity of particle size or percentage of the material that can be grouped within certain screen sizes are important factors in determining the relative flammability. The shape of the particle, which determines to some extent the surface area exposed for combustion in a dust cloud, is another factor that bears directly on the explosibility of the product. For men in the

plant these points are relatively unimportant because if tests have shown that the dust being produced or handled is capable of forming explosive mixtures with air, he can feel quite certain that the finest particles will be those normally found floating in the air.

Pressure Developed.

It would seem reasonable to expect the pressure produced in metal dust explosions to be lower than those that develop when carbonaceous dust clouds are ignited because the metal powders are converted during the combustion to oxides and presumably do not produce any great volume of gas as a product of combustion. It is somewhat surprising therefore to note the high maximum pressure and the high rates of pressure rise that have been measured in laboratory tests. Many of the pressures recorded are higher than those reported for some of the most explosive carbonaceous dusts, and the extremely high rate of pressure rise has led certain investigators to suspect that vaporization of the metal powder may occur and produce conditions closely approximating those that exist in explosive gas and air mixtures. Additional research will be necessary before this theory can be substantiated or disproved.

In the complete report of the investigation made to determine the explosibility of metal powders, a number of tables are used to present data on pressures produced at different concentrations and under different conditions. In this article, one table has been arranged to give, in condensed form, the essential data on the explosibility of metal powders, and similar data for representative carbonaceous dusts have been appended because most persons are more familiar with the damage caused by explosions of carbonaceous dusts than those caused by metal powders. The information available will permit a person familiar with carbonaceous dust explosions to draw comparisons and make at least an approximate evaluation of the fire and explosion hazard in metal powder plants. Table 1, which includes information on the ignition temperature of quiescent layers of metal powder and metal dust clouds, as well as the maximum pressure and rates of pressure rise, can be used in comparing the relative flammability of the powders tested.

In comparing the ignition temperatures given in Table 1 for a quiescent powder and a dust cloud, it will be noted that there is no consistent relation between the two figures. It is difficult to explain why in some cases the dust cloud ignited at a lower temperature than required for the static dust. The only explanation we can offer at the present time is that in some cases prolonged heating of the powders on a hot surface produces a condition which permits the ignition at a lower temperature than is otherwise possible. On the other hand, in a moving dust cloud the powder may come in contact with the heated surface for only a short period. This is a possible explanation of the cases in which the quiescent powder ignites at a lower temperature than the dust cloud. In the other case the only possible explanation is that the shape of

the powder permits the exposure of thin edges when the dust is in suspension, and these edges or fine projections can be ignited at a temperature somewhat lower than that required to ignite the product when the particles are packed together.

Table I.

Ignition Temperatures and Explosibility of Metal Powders with Comparable Data for Several Carbonaceous Dusts.

Metal	Ignition Temp., °F. Quiescent Powder	Ignition Temp., °F. Dust Cloud	Maximum Pressure lb./sq. in.	Pressure Rise lb./sq. in./sec. Average	Pressure Rise lb./sq. in./sec. Maximum
Aluminum, atomized	...[1]	1292	58	1050	2250
Aluminum, stamped	1085	1193	62	2170	5700[2]
Antimony	626	779	20	90	150
Cadmium	482	1058	..[3]	....	....
Chromium	1247[4]	1652	..[3]	....	....
Copper	518[5]	1292	..[3]	....	....
Dowmetal (magnesium - aluminum alloy)	896	806	56	1600	2570
Iron Carbonyl	410	608	31	660	1200
Iron, milled	860	1436	..[3]	....	....
Iron, reduced	554	599	36	230	430
Lead, atomized	518	1310	..[3]	....	....
Lead, stamped	572	1076	..[3]	....	....
Magnesium, milled	977	1004	65	1600	3160
Magnesium, stamped	887	968	72	1450	4760[2]
Magnesium-aluminum, milled	878	995	62	2350	3000
Manganese	...	842	31	220	400
Silicon	1742	1427	62	440	1180
Tin, atomized	806	1166	34	500	850
Titanium	860	896	52	750	1640
Zinc	896	1112	35	710	1350
Zirconium	410	...[6]	42	600	2570

Similar Data for Carbonaceous Dusts.

Metal	Ignition Temp., °F. Quiescent Powder	Ignition Temp., °F. Dust Cloud	Maximum Pressure lb./sq. in.	Pressure Rise lb./sq. in./sec. Average	Pressure Rise lb./sq. in./sec. Maximum
Corn Starch	615	716	51	830	1590
Peat Moss	...	887	58	680	1120
Pittsburgh Coal Dust	...	1130	46	370	780
Wood Pulp	522	1040	53	580	1000

[1] Temperature rise in powder at 1292°. No other evidence of ignition up to 1652°.

[2] This extremely high value should be accepted with caution because of possible errors in determining maximum slope of pressure time curves.

[3] This powder not ignited by standard spark in Hartmann apparatus. Ignition produced by pellet of magnesium and barium peroxide.

[4] Reaction noted at 1247°. No other evidence of ignition.

[5] Powder oxidized rapidly at 518°. No other evidence of ignition.

[6] Dust cloud ignited when blown through furnace at room temperature.

Explosion Prevention.

Dust explosions may be prevented if the production of dust clouds can be controlled or all possible sources of ignition can be eliminated. These two major principles have been the basis for the codes or recommendations for the prevention of carbonaceous dust explosions which have been developed by the Dust Explosion Hazards Committee for a number of different industries.* The same general rules are applicable in plants producing or handling metal powders, and specific recommendations for metal powder plants based on the results of the laboratory work now being reported probably will be incorporated in new codes being considered by the committee.

Dust control can generally be depended upon to provide protection against dust ignitions wherever it is possible to collect the dust at the point of production and prevent the dissemination of any dust into the atmosphere of the room or enclosures where the quantity in suspension in the air could increase until it reached an explosive concentration. Natural ventilation and positive exhaust or suction systems may be employed for dust control, and companies specializing in dust-collection equipment have developed a number of different types of both wet and dry dust-collecting systems to meet different needs. In some cases dust production can be eliminated by the employment of wet grinding and handling of the product in sludge form, but the substitution of such methods for a dry system may introduce many other serious problems or simply transfer the explosion hazard from the grinding to the drying department.

The elimination of possible sources of ignition is a somewhat less dependable method of preventing dust explosions because there are so many possibilities of a spark or flame being produced by conditions beyond the control of the plant operator. Attention has previously been called to the ease of ignition of many of the metal powders, and the difficulty of eliminating all static sparks, electric arcs, flames and heated surfaces in manufacturing plants is readily apparent. The fact that many of the fine dusts can be ignited by static sparks of very low energy emphasizes the necessity of thoroughly grounding all equipment and the building itself to remove any charges of static electricity. Lightning protection for all buildings is essential, and the possibility of metal powder accumulations forming grounds other than those originally provided should be considered.

The use of carbon dioxide, nitrogen or other gases to reduce the oxygen content of atmospheres within enclosures has generally been found to be an effective method of preventing ignitions of carbonaceous dusts. In the tests that have just been completed, it was found that some of the metal powders

*National Fire Codes for Prevention of Dust Explosions, published by the National Fire Protection Association.

could be ignited by sparks in pure carbon dioxide, and for a few of the powders pure nitrogen provides only a narrow margin of safety against ignition. If ignited, magnesium will burn in nitrogen to form magnesium nitride. Atmospheres of helium or argon were found to be more effective than carbon dioxide and nitrogen in preventing ignition of the metal powders, but their use in commercial operations is not considered practical unless provision can be made to prevent loss of the gas from the powder producing or handling equipment.

These results indicate that dependence for protection against dust ignitions should not be placed on atmospheres with reduced oxygen content obtained by the introduction of carbon dioxide or nitrogen unless laboratory tests have demonstrated their effectiveness.

Protection Against Destructive Pressure.

Probably the most important information needed in any attempt to provide protection against dust explosions is data on the maximum pressure that can be expected and the maximum rate of pressure rise. With such information available, it is frequently possible to design a machine enclosure or a building wall sufficiently strong to withstand the pressure until it can be dissipated through a vent or outlet to the outside of the building. Venting has been found quite effective in providing protection against structural damage by explosions of carbonaceous dusts; and the ratio of venting area to building volume, as well as the spacing or location of the vents, has been determined for certain types of plants and equipment.

Only a few opportunities have been presented to study the possibility of providing vents for the release of pressure produced in explosions of metal powders. Production of many of the metal powders is a comparatively new industry, and the materials have generally been manufactured or handled in small separate buildings. Explosions have wrecked or seriously damaged these small buildings. In a few cases where more substantial buildings have been provided to house the dust-producing equipment, explosion vents or hinged windows have been installed in the ratio of about 1 square foot of vent for each 25 cubic feet of room volume. Information available indicates that such vents have proved satisfactory and prevented structural damage to the building where no part of the enclosure was a greater distance from the vents than the least horizontal or vertical dimension of the room in which the ignition occurred. It is necessary, of course, in providing such protection to be sure that the vents will operate before the pressure of the explosion is sufficient to break down other walls of the room, and that there are no means of communication through which flames could be forced into adjoining enclosures where dust may be present.

The possibility of providing effective vents for explosions of some of the powders that showed unusually high rates of pressure rise in the laboratory

tests has not been established. The difficulty of providing suitable vents is apparent when it is noted from the table that in at least one case the maximum rate of pressure rise exceeded 5000 pounds per square inch per second. The maximum pressure was reached less than 0.02 second after ignition occurred. It is obvious that, in such cases, special types of vents and very close spacing will be necessary. An N.F.P.A. Committee on Explosion Venting is being organized to study the venting of explosions and to prepare recommendations for the safe release of pressures produced in ignitions of both dust and gas. It is hoped that research work planned by the committee will produce information on the size, type and location of vents necessary to release harmlessly the pressure produced in metal dust explosions. Until more detailed information is available, it will be wise for plant operators not only to guard against all possible chances of metal dust ignitions, but to segregate hazardous operations and provide the maximum possible area of vents, such as windows, weak walls, or light roofs, for any buildings where metal dust explosions may occur.

Star-Ledger.

The linoleum and camouflage drying cell building (wreckage in foreground) covered an area of 180 by 190 feet. It was 50 feet in height. The explosion of naphtha vapors in one of the eleven drying cells in the building caused this wreckage.

Congoleum-Nairn Co. Explosion.

One of the most serious industrial fire losses affecting the war effort during the past summer was the result of an explosion that wrecked buildings of Congoleum-Nairn Company at Kearny, New Jersey, on August 19, 1943, causing a loss of 12 lives. The loss has been estimated in excess of $2,000,000, exclusive of losses due to interruption to production. In addition to the usual manufacture of linoleum, the section of the plant where the blast occurred was occupied by a tenant concern manufacturing camouflage materials for the Army.

Description of Property Involved.

The building in which the explosion initiated was of reinforced concrete construction covering an area of 180 by 190 feet, and was known as Building No. 12. It contained eleven drying cells, each of which was 190 feet long, 12 feet wide, and 50 feet high. Cells 1 to 5 were used for linoleum drying. Cells 6 to 8 were used for camouflage drying following a waterproofing process. Cells 9 to 11 were mainly used for storage.

Adjacent to the north walls of cells 1 to 8 was a 5-story building of brick and reinforced concrete covering an area of 22 by 106 feet. The top floor of this building was used for coating, charging, and withdrawing material from the cells. The lower floors were used for storage. Attached was a one-story addition 38 by 106 feet in area, of brick construction with a plank and timber roof. There was another 4- and 5-story building near by. This was likewise seriously damaged in the explosions. Other near-by buildings were damaged by débris and the force of the blast.

The entire property was protected by a wet-pipe sprinkler system.

Processes Involved.

As previously indicated, three of the drying cells were being used for the drying of camouflage which was the property of a tenant concern. The camouflage consisted of nets sewed into a continuous piece and passed through a bath of solution, then through rollers and into the top of a drying cell, where an employee was stationed to guide the festooning. It is reported that approximately 8 hours were required to charge one of the cells, and that more than a thousand gallons of naphtha solvent were required for a charge. Drying was accomplished by keeping the cells hot for a day by means of steam-heated drying coils.

The drying cells, as originally constructed for use with linoleum, were merely provided with sufficient ventilation to permit employees to work at the

Note: This account has been prepared from data obtained from various unofficial sources; no official report has as yet been released.

Star-Ledger.

Ruins of the Congoleum-Nairn Company plant at Kearny, New Jersey, following the explosion of August 19, 1943, which took a toll of 12 lives and caused $2,000,000 property loss. Camouflage nets treated with waterproofing solvents in the five-story building (the ruins of which are shown at the right) were dried in huge drying cells shown in ruins in the foreground.

foreground.

Star-Ledger.

Viewed from another direction. This shows the wreckage of the drying cells used for drying both linoleum and camouflage netting. This structure of heavy reinforced concrete lacked an adequate ventilating system and explosion relief vents. Thus a naphtha vapor explosion in one of the drying cells demolished the entire structure and damaged near-by buildings, one of which appears in the background at the left.

Star-Ledger.

Better appreciation of the great violence of this explosion can be obtained from this view, showing the tangled reinforced concrete slab and the apparently insignificant size of the firemen working atop the wreckage. The fire which followed the blast was fought by the combined efforts of five fire departments, assisted by automatic sprinklers in the various plant buildings.

top level during the festooning process. This ventilation was accomplished by having fans remove and replace air through a duct system. The only additional ventilation provided for cells used in camouflage drying was the addition of one window fan of 30- or 36-inch size at the ground level of the three cells used for this purpose. These fans were of sufficient rated capacity to move the air content of the cell in seven to nine minutes. There was apparently no provision for explosion venting.

Cause of the Explosion.

The blast occurred at 5:30 P.M. in cell No. 8, just as steam was turned on for the drying process. Cell No. 6 was being turned off, and cell No. 7 was being emptied. The actual cause of the ignition, if known, has not been released by Army investigators. However, it is known that ordinary electric lights were in use at the time and could have caused the ignition of the vapors of the solvent, said to have consisted of 75 per cent naphtha.

Story of the Fire.

Twelve employees lost their lives as a result of being crushed by the heavy débris of the wrecked buildings. At least eight other persons were seriously injured.

Fire was confined to the débris and was fought by fire apparatus and fireboats from five near-by cities. Several hundred sprinkler heads operated in the fire area and appear to have been generally helpful, although fire departments complained of low water pressure due to broken sprinkler lines of various sizes from ¾-inch to 6-inch pipe.

The accompanying photographs describe better than words the tremendous damage wrought by this explosion. While it was believed that the work of coating camouflage nets would not be resumed at this plant, other war work was back in production within a very few days.

lowed the blast was fought by the combined efforts of five fire departments, assisted by automatic sprinklers in the various plant buildings.

Venting of Tanks Exposed to Fire.

By James J. Duggan (Member N.F.P.A.),
G. H. Gilmour and P. F. Fisher

The most severe hazard to which a vessel may be subjected is in most cases exposure to external fire and the attendant rise of internal pressure. Complete specifications for the release of this overpressure applying to unfired vessels are lacking, and the present standards in the opinion of the authors are inadequate.

Part 1 of the paper on which this article is based outlines tests and experience with vessels enveloped in flame, and sets forth an observed rate of heat absorption. Parts 2 and 3 state the theory on which the solution is based and express it mathematically in simple, useful formulas for unfired pressure vessels and atmospheric tanks in either gas or liquid service.

This article is a condensation of a paper, "Requirements for Relief of Overpressure in Vessels Exposed to Fire," presented to the Petroleum Division of the American Society of Mechanical Engineers at the Semi-Annual Meeting, Los Angeles, June 17, 1943. The paper and discussion will appear in the ASME Transactions. Copies are not now available, but at a later date the Transactions may be obtained from the American Society of Mechanical Engineers, 29 West 39th St., New York.

The authors, connected with the Carbide and Carbon Chemicals Corporation, South Charleston, West Virginia, unit of the Union Carbide and Carbon Corporation, have, over a period of years, been giving extensive study to the problems outlined in this article. N.F.P.A. members will recall the article, "Testing and Inspection for Fire Prevention," by Mr. Duggan in the QUARTERLY for July, 1938.

Explosion, or pressure rupture, of gasoline and other tanks exposed to fire, has been responsible for many casualties and extensive property damage. Numerous examples will be found in accounts of gasoline and oil fires published in the QUARTERLY (October, 1926, page 190; July, 1930, page 105; July, 1934, page 53; January, 1938, page 227; October, 1938, page 143, and January, 1939, page 271). It should be noted that in the present article the authors distinguish between true explosions due to the ignition of an explosive mixture of flammable vapor and air in the tank, and failures due to excessive internal pressure, which often have violent effects and are commonly referred to as explosions. The present paper discusses venting to relieve excessive internal pressure due to heat; explosions of vapor-air mixtures cannot be relieved by any such vents as are discussed here. Flame arresters, rather than vents, are the safeguards commonly employed to safeguard against vapor-air explosions.

While the authors of the present article present evidence to show that present N.F.P.A. standards for emergency venting (National Fire Code for Flammable Liquids, Gases, Chemicals and Explosives 1943, page 19) are inadequate to prevent pressure rupture of tanks surrounded by fire, the available fire record shows that in the majority of tank failures the emergency vents were far below the existing N.F.P.A. standards, and in many cases no vents were provided in addition to the normal operating vents. The N.F.P.A. Committee on Flammable Liquids, which has jurisdiction over the N.F.P.A. standards on emergency venting, may be expected to review the existing standards in the light of the data presented in this article.—ED.

PART ONE.

Observed Rate of Heat Absorption.

According to some regulatory and recording associations, the majority of vessel failures during exposure to fire are attributed to inadequate relief capacities. Yet there is a definite lack of investigated data which may be applied to determine the necessary relief areas for that condition. Much effort was expended to collect such data which are outlined below. It is believed that additional information of the kind is existent.

The only standards available for emergency relief specifications applying to process and storage equipment are those published by the National Fire Protection Association[1,2] and the National Board of Fire Underwriters.[3] These are based upon "The Rates of Vaporization in Gasoline in Storage Tanks Exposed to Fire," which was prepared by the engineering office of the American Petroleum Institute. This is a theoretical analysis based on the assumption that heat will be absorbed by the contents at a rate of 6000 B.t.u. per hr. per sq. ft. of surface wetted by the liquid contents. The authors believe this assumption to be inadequate for reasons which are apparent below.

The authors conclude that pressure relief areas should be designed on a basis of 20,000 B.t.u. per hr. per sq. ft. of surface wetted by the contents and exposed to fire. Where vessels are in confined areas, buildings, or enclosures, and an intense fire could occur, no reduction from the maximum height of the surface to be wetted by the contents should be used when designing emergency pressure relief. Where such equipment is in open areas, properly spaced, dyked, and otherwise installed in accordance with recognized standards, it is considered not economical to design for a heat-input height of less than 40 ft. and unsafe under average conditions to use less than 30 ft. Further, no reduction of the heat absorption rate of 20,000 B.t.u. is proposed (except for atmospheric working pressure tanks as outlined in Part Three of this paper) to allow for the possibility that vessels may not be completely surrounded with flame during a general fire.

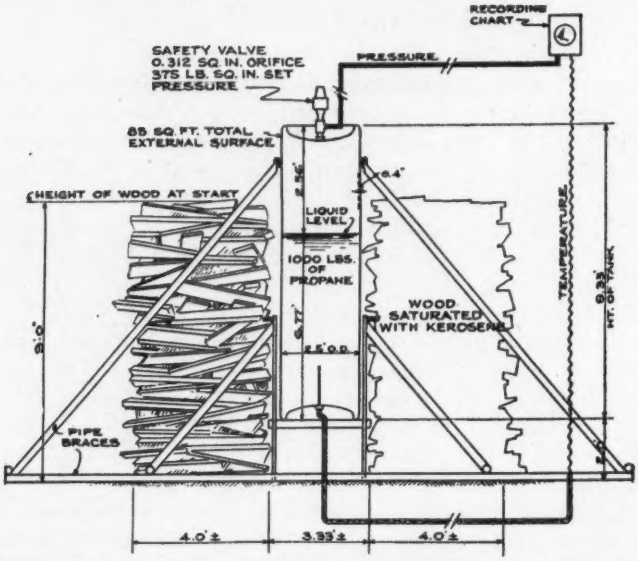
Tests of Tanks Exposed to Fire.

In Part One of the paper, seven tests of vessels exposed to fire by four separate organizations are analyzed. These tests gave an average rate of heat absorption of 24,000 B.t.u. per hr. per sq. ft. of surface wetted by the contents. None of these tests were made on large vessels, the biggest being 3000

[1] N.F.P.A. "Flammable Liquids Ordinance," published in National Fire Codes for Flammable Liquids, Gases, Chemicals and Explosives, Edition of 1943, and in separate pamphlet form.

[2] "Crosby-Fiske-Forster Handbook of Fire Protection," N.F.P.A. Flammable Liquids Ordinance, N.F.P.A., Boston, Mass., 1941, Ninth Edition, pages 107 and 108.

[3] Containers for Storing and Handling Flammable Liquids," N.B.F.U. Pamphlet No. 30, N.B.F.U., New York City, N. Y., 1941, pages 37 and 38.



Diagrammatic representation of the fire exposure test of the 300-gallon propane tank, the basis of existing venting standards for liquefied petroleum gases and for tank cars developed from tests by John F. Fetterly, Bureau of Explosives, 1928.

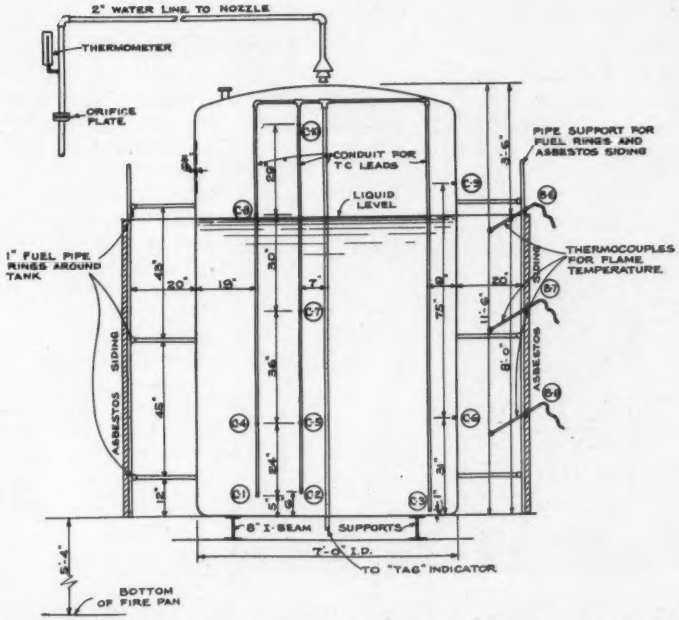
gal. nominal capacity. They were tests on a 1000 lb. capacity propane tank[4] which gave a maximum rate of heat absorption of 23,000 B.t.u. per hr. per sq. ft., on a 24 sq. ft. steel plate[5] showing 32,000 B.t.u. per hr. per sq. ft., on a 150-gal. gasoline compartment[6] affording heat rates of 20,000 to 29,000 B.t.u. per hr. per sq. ft., and four of our own tests, concluded in 1940, on a 3000-gal. tank containing water which gave an average rate of heat absorption of 19,700 B.t.u. per hour per sq. ft.

In two of the seven tests which are cited in the paper, the observed heat input rate was calculated by multiplying a measured rate of water flow by a measured rise in temperature of the water. Another calculation consisted of measuring the rate of rise in temperature of a known quantity of water in a tank. Two other heat input rates were calculated from the rate of vaporization of liquids from tanks exposed to external fire; thus the heat input rate of approximately 20,000 B.t.u. per hr. per sq. ft. for vessels containing liquids is

[4] "The Determination of the Relief Dimensions for Safety Valves on Containers in which Liquefied Petroleum Gas is Charged and when the Exterior Surface of Container is Exposed to a Temperature of 1200° F.," J. F. Fetterly, Bureau of Explosives, 1928.

[5] "Opacity of Water to Radiant Heat Energy," Underwriters' Laboratories, Inc., Bulletin of Research No. 3, Chicago, Illinois, January, 1938. Abstracted in N.F.P.A. QUARTERLY, April, 1938, page 300.

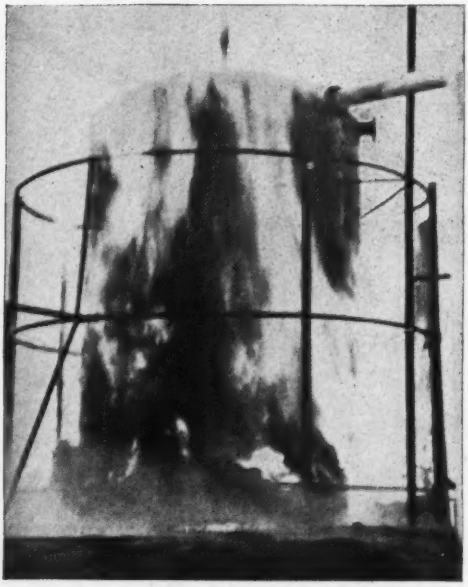
[6] "Impact, Hydrostatic, and Fire Tests—Aluminum Alloy Compartments for Tank Trucks," Aluminum Company of America, New Kensington, Pennsylvania, 1930.



Sectional diagram of equipment used in tank fire exposure tests, Carbide and Carbon Chemicals Corp., South Charleston, West Virginia. Rate of absorption of heat from fire surrounding the tank was determined from the rise in temperature of a measured flow of water over the tank, or from the increase in temperature of the contents.

established by means of simple calculations without resort to any assumption of the mechanism of heat transfer or the temperature of the flame. In the paper, however, the theory of the heat transfer process is developed both as a matter of interest and as a means to show that a heat input rate of 20,000 B.t.u. per hour per sq. ft. is reasonable. The difficulties in measuring the true temperature and black body coefficient* of the flame and the shape factor* involved in the transfer of radiant heat from the flame to the wall of the vessel are recognized. But by assuming that the black body coefficient and the shape factor are unity, then the theoretical flame temperature required to transfer the heat may be calculated, and this is referred to throughout the paper as the effective flame temperature. The magnitude of the effective flame temperature required to transmit 20,000 B.t.u. per hr. per sq. ft. from a flame to a tank is

*The transfer of heat by radiation depends upon the character of the surface and its shape. Standard measurements assume a black, non-reflecting surface, with radiation perpendicular to a flat surface. When the character and shape of the surface are different, the attendant variations in heat transfer by radiation are expressed in terms of "black body coefficient" and "shape factor."—Ed.



Typical view of one of the fire tests to determine rate of heat absorption. Liquefied hydrocarbon fuel was released through three rings of pipe. An asbestos shield was used to avoid distortion of results by wind effects (one section in place at right). The results corroborated data from other sources as a result of which the authors propose substantially greater emergency venting areas than have heretofore been used.

approximately 1400° F. This is considered to be a reasonable value, thus giving theoretical support to the observed heat input rate.

Since the paper was written, reports were received of four other tests conducted in 1938 by one of the large producers and distributors of propane and butane gases. Two of these were sufficiently detailed to afford data on heat absorption rates. One on a 100 lb. capacity propane container gave an average rate of 21,600 B.t.u. per hr. per sq ft. The other on a 1000-gal. capacity container showed a heat input of the order of 33,000 B.t.u. per hr. per sq. ft. for a short time.

Another paper has come to hand citing a test (about 1925) by Mr. H. H. Hall of the Standard Oil Company of California. This was said to have been made on a horizontal water tank about the size of a tank truck placed inside of a dyked area flooded with burning gasoline. Energy was absorbed at a rate of 416 B.t.u. per min., or 24,960 B.t.u. per hr. per sq. ft. of surface wetted by the contents.

Analysis of Vessels Exposed to Accidental Fire.

In evidence are the reports of five tank failures from accidental fire exposure. These were all vertical, cylindrical tanks with dished heads. They were designed for 5 lb. per sq. in. gage working pressure with a safety factor of five, but operated at atmospheric pressure. Four were 10 ft. 8 in. dia. by

18 ft. 10 in. overall length, 10,200 gal. nominal capacity, with 583 sq. ft. of wetted surface when nominally full (700 sq. ft. total). The fifth tank was only 12 feet high and of 7000 gal. nominal capacity. All of the tanks were provided with 3 in. iron pipe size vents, which size was in excess of N.F.P.A.-N.B.F.U. standards.

Two of the largest tanks were severely exposed for about fifteen minutes. They were equipped with Underwriters' Laboratories tested vent units and flash arresters. Both were empty at the time but were in diethanolamine service. This compound is stable at elevated temperatures, has a boiling point of 514° F., and a flash point of 140° F. The three-inch diameter vents were adequate for a heat of absorption rate of 7000 B.t.u. per hour through 583 sq. ft. of wetted surface. The vessels failed from internal pressure. No explosions were noted by observers. Calculations by the formula in the paper give a developed internal pressure of 25 lbs. per sq. in. gage from expansion of the contained air. This is great enough to cause the type of failure which occurred.

The third tank of 7000-gal. capacity was exposed for only about five minutes. It contained 3300 gals. of ethyl butyric acid, which does not break down when boiled at 381° F. Three hundred (300) gallons were vaporized, necessitating a rate of heat absorption of 20,000 B.t.u. per hr. per sq. ft. of wetted surface for a six-minute exposure.

The fourth vessel of 10,200-gal. capacity was exposed about ten minutes. This contained 3025 gals. of ethyl butraldehyde, which boils at 240° F. and probably undergoes partial dissociation above that temperature. At a 20,000 B.t.u. per hr. per sq. ft. rate of energy absorption, vaporization of contents would have built up pressure in the tank to 24 lbs. per sq. in. gage despite the 3-in. atmospheric vent apparatus. This, coupled with probable partial breakdown of the contained vapor, resulted in rupture of the vessel.

A fifth tank (10,200-gal. capacity), exposed on one side only, contained 2540 gals. of triethylene glycol, a very stable and non-volatile compound which boils at 620° F. The 3-in. vent had been reduced to 1½ inches. The contents were of such low temperature immediately after the fire that the hand could be held on the portion of the tank containing liquid. The vessel failed at the top head seam. On-the-spot observations and subsequent investigation did not indicate internal explosion. Calculations by the developed formula gave a possible internal pressure of 35 lbs. per sq. in. gage from expansion of the contained vapor-air mixture.

Recently, a number of additional tanks like the above were involved with fire. The analysis of the individual failures gave results similar to those outlined. It is further significant that some of these 10,200-gal. capacity tanks were equipped with 4-in. size atmospheric vent apparatus rather than the standard 3-in. size, and yet, were damaged from excessive internal pressure.

The contents were acetone, a stable compound, and the relief capacity was compatible with a designed heat absorption rate of 10,850 B.t.u. per hr. per sq. ft. of wetted surface when nominally full.

Height of Effective Flame Temperatures.

Since the heat-input to a vessel exposed to fire depends on the mean effective flame temperature, it is necessary to estimate the height to which temperatures of the order of 1400° F. may be expected.

The authors have observed aluminum (1125 to 1490° F. melting point), glass (1400 to 1600° F. melting point), and brass (1575 to 1800° F. melting point) melted more than 20 ft. above grade during flammable liquids spillage fires in open areas in less than an hour. Drooping type failures of unloaded structural steel, necessitating temperatures of at least 1000 to 1200° F., at elevations of 30 to 40 ft. above the spillage have also been noted under similar circumstances. An aluminum (1216° F. melting point) tank 17 ft. in diameter by 19 ft. 4½ in. high was known to have been surrounded by fire and completely melted down in a matter of a few minutes. The tank was one-third full.

Since the paper was written, observations were made of the flame temperatures of burning butadiene. Temperatures over 1000° F. at 23 ft. above a 51 sq. ft. pan were read. This was done in the open, using an unshielded thermocouple. An estimated ten-mile an hour wind was blowing at the time.

These observations led to the suggested 30 ft. minimum and 40 ft. preferable design heights* previously mentioned.

Conclusions, Part One.

The tests and experiences analyzed would indicate that 20,000 B.t.u. per hr. per sq. ft. of wetted surface exposed to fire is a safe minimum rate of heat absorption as a basis for the design of emergency relief capacities. Observations and calculations indicate this to be commensurate with an effective flame temperature of about 1400° F. completely around the vessel exposed. Modification of this rate is suggested for atmospheric tanks above 15 ft. in diameter, as outlined in Part Three of the paper, to allow for the lessened possibility of complete envelopment in flame and lengthened time required to heat the contents throughout.

Substantial fire-resistive insulation will, of course, lower the heat absorption rate proportional to the reduction effected in the heat transfer rate through the tank wall when the insulation is exposed to hot gas temperatures

*It is often assumed that fires at the ground level have little exposure effect on structures high above the ground. However, the experience of ignition of the upper floors of high buildings by exposure fires in adjacent low buildings shows that heat may be transmitted by radiation and convection to very considerable heights. The authors' proposal that vents be designed on the basis that fire around a tank will affect it for a height of 30 to 40 ft. above the ground is certainly not unduly conservative, and it might be argued that fire exposure should be assumed to affect the entire height of the tank.—Ed.

of 1400° F. The authors suggest that this lowered rate not be used in calculating the size of relief connection, although it may be reflected in the capacity of the relief device.

The authors realize that the observed rate of 20,000 B.t.u. is an increase over accepted practice (6000 B.t.u.) of considerable magnitude. However, the increase is in the direction of safety, and in view of the evidence collected, a substantial increase is needed. Naturally, many installations exposed to fire are so completely destroyed that neither rate can be substantiated on the basis of remaining evidence. Authorities and observers agree, however, that many of the failures were definitely due to excessive internal pressures and not to combustion explosions as commonly believed.

PART TWO.

Requirements for Relief of Pressure† Vessels.

Having established a rate of heat absorption for a vessel containing liquid exposed to fire, the next logical step is to correlate the several variables of container dimensions, working pressures, and properties of contents into simple, useful expressions whereby the necessary relief capacity can be calculated. This may be done by equating the vaporization rate (produced by the energy absorbed) to the flow through the free area of the relief opening.

There are two expressions for the flow of vapor through an opening, one for flow above and one for flow below the critical or acoustic velocity. The pressure at which this change in flow occurs ranges from 10 to 15 lbs. per sq. in. gage approximately, depending upon the properties of the gas flowing. From a practical viewpoint, the flow of all vapors from pressure above 15 lbs. per sq. in. gage is in excess of the critical velocity; so that one orifice equation may be used in computing the relief requirements for vessels operating above that pressure. For that reason, Part Two of the paper has been prepared to apply only to vessels operating at pressures above 15 lbs. per sq. in. gage. Part Three covers atmospheric pressure storage.

The authors emphasize that this discussion applies to relief areas, relief connections, and calculated flow capacities of free areas.* It is not a discussion of relief devices or apparatus, relative merits of types, etc.

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† Pressures above 15 lbs. per sq. in. gage.

*In determining the relief vent sizes given in this article, a coefficient of discharge of 0.83 was used for flows through a short tube (a tank connection) at pressures above 15 lbs. per sq. in. gage, and a coefficient of 0.70 for flows at pressures not to exceed 0.50 lb. per sq. in. gage. The actual discharge capacity of venting devices may vary considerably from the nominal diameter of the vent, and where the venting device is connected to the tank by a length of pipe, the friction loss in the pipe will naturally reduce the vent capacity. Many safety valves now in general use do not have discharge capacity approaching that of their pipe connections.—Ed.

Formulae for Vent Sizes.

It was concluded that two formulas, if properly applied to vessels to operate at pressures above 15 lbs. per sq. in. gage, would indicate the relief capacity in terms of free area of opening required to limit the pressure rise within to a specified maximum.

The diameter of the necessary free circular opening, in the form of a pipe connection, when the volatile liquid contents are vaporized by the heat of external fire, is determined by the following formula:

$$d = \sqrt{\frac{97.3\ S_W}{(P + 14.7)}} \left(\frac{P + 448}{3333.3}\right) \qquad (1)$$

When a gas or vapor (the only contents) is expanded by the heat of external fire, the diameter is

$$d = \sqrt{\frac{0.0803\ S}{\sqrt{(P + 14.7)}}} \qquad (2)$$

In equations (1) and (2) d is in inches, S_W is surface wetted by the contents and exposed to fire in sq. ft., S is total surface exposed in sq. ft., and P is the maximum relieving pressure in lbs. per sq. in. gage.

The Theory and Method.

When a vessel is involved in fire, heat is absorbed by the contents and the temperature rises. If the contents are liquid, vapors are formed and boiling eventually occurs; if the contents are vapors or gases, rapid expansion takes place. In either case, the relief capacity must be equivalent to the vaporization rate or the rate of volume increase, as the case may be, or uncontrolled pressure rise will result and rupture of the vessel may follow.

On this basis, it is possible to compute the required relief area by setting the equation of relief capacity equal to the equation of the rate of vaporization or the rate of volume increase.[8] When this is done, two expressions result which are the origin of formulas (1) and (2) and which include, in addition to the symbols S_W, S, and P, the terms which relate the properties of the contents and which we have called the contents factor.

The contents factor for liquids is $(T/Mr^2)^{1/4}$ in which T is boiling point in degrees Fahrenheit at the relieving pressure, M is the molecular weight, and r is the latent heat of vaporization at the temperature T in B.t.u. per pound. In the paper, we have explained and shown in detail how this term may be reduced to the more simple $(P + 448)/3333.3$. This was done by plotting the values of the contents factor for the known hazardous liquids against pressure and from the graph, choosing a single, safe, but economical value for the many

[8] The equation of the rate of expansion of confined vapor was based on the assumptions that the gas laws hold and that heat is absorbed by natural convection.

volatile liquids to be contained. However, the contents factor may be computed directly for any liquid if desired.

The contents factor for gases is $(F/C_pM^{1/2})^{1/2}$ in which F is a function of the physical properties and is given as a numerical value in heat transmission literature, C_p is the specific heat of the gas or vapor, and M is the molecular weight. This factor was evaluated for a number of representative gases having large numerical values, and the properties of air were found to give the largest. By substitution, the factor was then expressed in terms of pressure and temperature. It was then possible to reduce the general expression to formula (2) by inserting temperature limits for the initial vapor temperature (0° F.) and final tank wall temperature. The final wall temperature to which a steel vessel of the usual "Code design" could be heated and remain intact at the relieving pressure was estimated to be 1100° F.

After determining the diameter of the relief area as outlined above, the relief capacity may be calculated by using the area in any one of the following orifice formulas as the case may require:

$$W = 262\ aP\sqrt{M/T}\ \text{lb. per hr. of vapor.}^{9} \tag{3}$$

$$Q = \frac{1682\ aP}{\sqrt{MT}}\ \text{cu. ft. per min. of free vapor at 68° F.}^{9} \tag{4}$$

$$Q = \frac{353\ aP}{\sqrt{T}}\ \text{cu. ft. per min. of free air at 68° F.}^{10} \tag{5}$$

$$W = 42.7\ aP\ \text{lb. per hr. saturated steam.}^{11} \tag{6}$$

In these a is the relief area in sq. in. and P is the relieving pressure in lbs. per sq. in. absolute, M is the molecular weight of the contents, and T is the contents vapor or gas temperature in degrees Fahrenheit absolute at the pressure P. For conditions of fire exposure, T is the liquid temperature corresponding to the relieving pressure; this temperature figure may be obtained from temperature-vapor pressure data in handbooks. For vessels in gas service, T is the temperature (absolute) at the relieving pressure; T may be computed by the gas law, $T/P = T'/P'$, when the initial temperature and pressure conditions and the safe relieving pressure are known. (These temperature figures are approximate, but are on the safe side.)

The relief apparatus should then be chosen of a capacity, based on approved flow test, to pass this calculated rate. Consideration may be given to multiple devices or multiple types as the user may desire.

[9] "A.P.I.—A.S.M.E. Code for Unfired Pressure Vessels," New York, New York, 1938 edition, page 74. Modification from a tapered nozzle to a short tube.

[10] Fliegner's equation.

[11] Napier's formula.

Conclusion, Part Two.

The formulas proposed give relief capacities much greater than are at present employed. In order that the results may be compared with known proposals or standards, Figure V has been included. On this it will be noted that Fetterly's[4] formula gives relief areas averaging about 10 per cent in excess of formula (1) at the pressure plotted; that formula (1) for volatile liquids gives relief areas about 50 per cent greater than those specified for steam; and that formula (1), when modified by the properties of water, gives relief areas about 50 per cent less than the regulations for steam boilers. (Comparison of unfired pressure vessels with steam boilers is hardly justified, but it does show that the results are in the logical direction when it is considered that about six times as much heat is required to vaporize water as compared to the volatile liquid considered.) Also appearing is Curve 6, showing relief diameter sizes based upon 6000 B.t.u. per hr. per sq. ft. of wetted surface. The relation between Curves 2 and 6 depicts the suggested increase of about 2.2 times in the diameter of the relief area which the authors believe will eliminate failures due to overpressure during fire exposure. It may also be noted that the calculated relief diameters for gases are about one-half of those for volatile liquids at 15 lbs. per sq. in. gage working pressure.

Figure VIII has been included to show how the relief area as calculated by formula (1) varies with pressure.

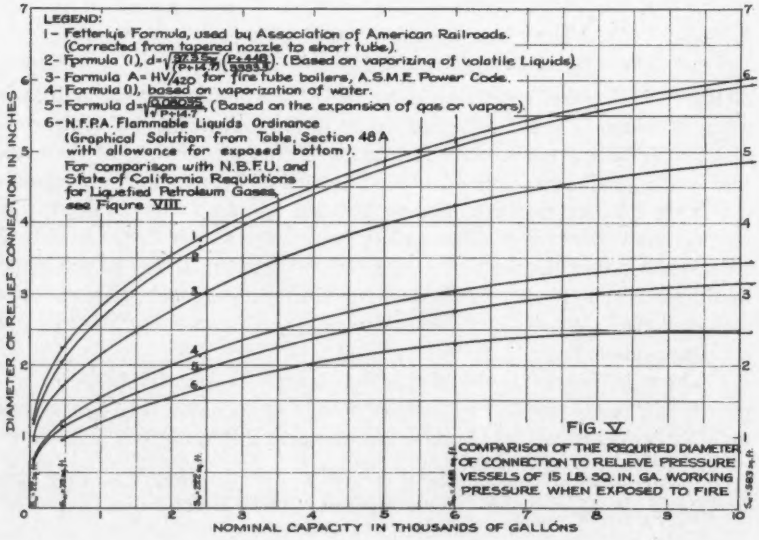
LEGEND:
1- Fetterly's Formula, used by Association of American Railroads. (Corrected from tapered nozzle to short tube).
2- Formula (1), $d=\sqrt{\frac{37.35\,w}{\sqrt{P+14.7}}\left(\frac{P+446}{938.1}\right)}$. (Based on vaporizing of volatile Liquids).
3- Formula A= HV/4220 for fire tube boilers, A.S.M.E. Power Code.
4- Formula (1), based on vaporization of water.
5- Formula $d=\frac{0.0805\,w}{\sqrt{P+14.7}}$, (Based on the expansion of gas or vapors).
6- N.F.P.A. Flammable Liquids Ordinance (Graphical Solution from Table, Section 48A with allowance for exposed bottom).
For comparison with N.B.F.U. and State of California Regulations for Liquefied Petroleum Gases, see Figure VIII.
DIAMETER OF RELIEF CONNECTION IN INCHES
NOMINAL CAPACITY IN THOUSANDS OF GALLONS

FIG. V

COMPARISON OF THE REQUIRED DIAMETER OF CONNECTION TO RELIEVE PRESSURE VESSELS OF 15 LB. SQ. IN. GA. WORKING PRESSURE WHEN EXPOSED TO FIRE

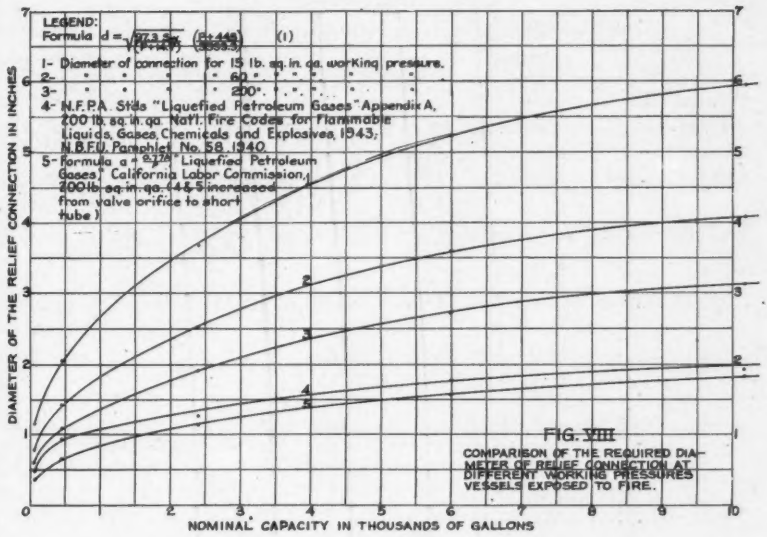
LEGEND:
Formula d = √(97.3 Σ/(P+14.7)) (Q=449/√(L/d^5)) (1)
1- Diameter of connection for 15 lb. sq. in. ga. working pressure.
2- " " " 60 " " " " " "
3- " " " 200 " " " " " "
4- N.F.P.A. Stds "Liquefied Petroleum Gases" Appendix A, 200 lb. sq. in. ga. Natl. Fire Codes for Flammable Liquids, Gases, Chemicals and Explosives, 1943; N.B.F.U. Pamphlet No. 58, 1940.
5- Formula a "Std" Liquefied Petroleum Gases," California Labor Commission, 200 lb. sq. in. ga. 44.5 increased from valve orifice to short tube)
DIAMETER OF THE RELIEF CONNECTION IN INCHES
NOMINAL CAPACITY IN THOUSANDS OF GALLONS

FIG. VIII
COMPARISON OF THE REQUIRED DIAMETER OF RELIEF CONNECTION AT DIFFERENT WORKING PRESSURES VESSELS EXPOSED TO FIRE.

PART THREE.

Requirements for Relief of Atmospheric[12] Vessels.

A considerable number of treatises, specifying the relief requirements for atmospheric storage tanks, have been available for many years. Various methods have been developed to establish the normal venting requirement, and at least three nationally known, reliable organizations[12] have agreed upon and proposed venting capacities necessary to limit internal pressure in the event of fire exposure. The fire records of the National Fire Protection Association clearly indicate the need and value of adequate emergency vent areas and emphasize the inadequacy of the usual normal relief capacity when a vessel is involved with intense fire.

In this part a recent investigation of the normal requirement is set forth and compared with previous methods. By the procedure used in Part Two for pressure vessels, the emergency requirement is developed, compared, and discussed.

The normal venting requirements were based upon 14 months' continuous record of the breathing action of a 440,000-gal. finished gasoline storage tank.

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[12] Covers pressures not to exceed 1 in. water external and 0.50 lb. per sq. in. gage internal pressure.

[13] Refer to Figures X and XIII, pages 151 and 152.

TABLE III.

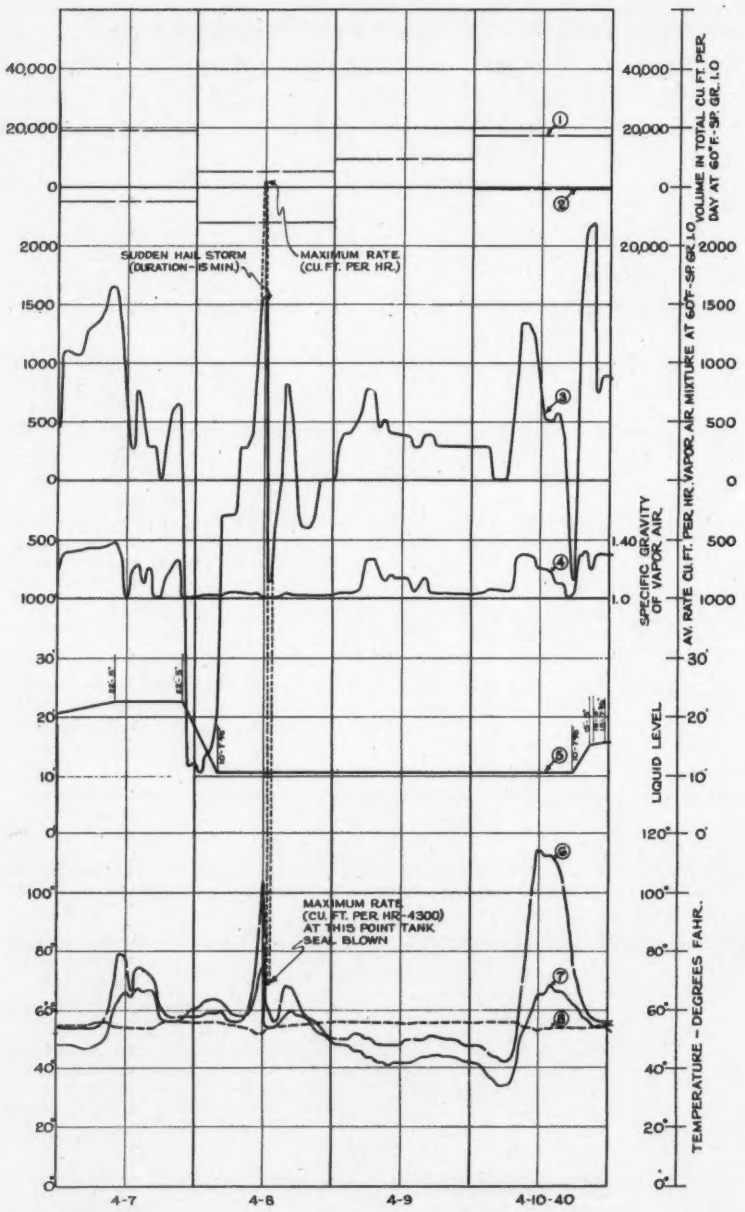
Observed and Calculated Data on the Maximum Breathing Rates of a 10,000-barrel,

Conditions:	Hail Storm April 8, 1940, 11:50 a.m. to 12:10 p.m. Case 1	Sudden Showers July 29, 1940, 3:40 p.m. Case 2	Sudden Showers May 31, 1940, 2:05 p.m. Case 3
Temperatures:			
Atmospheric	73° to 54° F. in 20 min.	104° to 74° F. in 45 min.	78° to 65° F. in 30 min.
Vapor contents	103° to 62 F.° in 20 min.	146° to 84° F. in 1 hr.	95° to 67° F. in 30 min.
Maximum rate of change (vapor)	98° to 70° F. in 7 min.	119° to 111° F. in 2 min.	92° to 74° F. in 15 min.
Liquid contents	52° to 56° F. in 20 min.	80° to 82° F. in 1 hr.	58° F. constant
Final tank wall about vapor space	56.0° F. (estimated average)		
Recorded vapor flow rate (Max.)	4300 cu. ft. per hr. when 1½ oz. per sq. in. vacuum seal blown	2650 cu. ft. per hr., when seal blown	*4450 cu. ft. per hr.
Liquid level	10 ft. 7⅝ in. (constant)	19 ft. 0 in. (constant)	0 ft. 9 in. (constant)
Vapor space quantities	Volume 45,200 cu. ft. Surface (S) 5170 sq. ft.	Volume 28,800 cu. ft. Surface (S) 3860 sq. ft.	Volume 64,600 cu. ft. Surface (S) 6720 sq. ft.
Rate of volume change (proportional to maximum abs. temp. rate as a gas)	18,850 cu. ft. per hr.	12,000 cu. ft. per hr.	*8400 cu. ft. per hr.
Proposed breathing rate (based on S/0.290 as derived. Pump rate to be added)	17,830 cu. ft. per hr.	13,300 cu. ft. per hr.	23,200 cu. ft. per hr.
Reid vapor pressure (lb. per sq. in. at 100° F.)	8.3 lbs. per sq. in.	8.3 lbs. per sq. in.	5.6 lbs. per sq. in.
Weather	Bright sun preceding storm, cloudy thereafter.	Hot sun shining before and after heavy rainstorm.	Cloudy with intermittent sun before shower; bright sun thereafter.
Remarks	Maximum condition (largest temperature drop in appreciable period found) used as basis of S/0.290.		

Finished Gasoline Storage Tank when Exposed to Extreme Atmospheric Changes.

Solar Heating May 5, 1940— 7 hrs. Case 4	Emptying May 1, 1940— 6½ hrs. Case 5	Emptying April 19, 1940— 5 hrs. Case 6	Filling Jan. 2, 1940— 7 hrs. Case 7	Filling Jan. 9, 1940— 22 hrs. Case 8
39° to 74° F. in 7 hrs.	73° to 61° F. in 30 min.	58° to 57° F. in 1 hr.	28° F. constant	31° to 26°. F in 5 hrs.
32° to 112° F. in 6 hrs.	78° to 62° F. in 45 min.	60° to 58° F. in 1 hr.	56° F. constant	33° to 32° F. in 4 hrs.
48° to 82° F. in 1 hr. (9 to 10 a.m.)	78° to 64° F. in 30 min.	As above	None	As above
50° F. constant	55° to 57° F. in 10 min.	55° F. constant	42° F. constant	40° F. constant
*2800 cu. ft. per hr.	*4275 cu. ft. per hr.	*4050 cu. ft. per hr.	4220 cu. ft. per hr.	3930 cu. ft. per hr.
1 ft. 6⅜ in. (constant)	11 ft. 7¾ in. to 3 ft. 10¾ in. in 6⅓ hrs. Avg. 1.225 ft./hr.	29 ft. 5 in. to 17 ft. 4 in. in 5 hrs. Avg. 2.42 ft. per hr.	1 ft. 9¾ in. to 4 ft. 8½ in. in 7 hrs. Avg. 0.414 ft. per hr.	3 ft. 6½ in. to 12 ft. 2½ in. in 23 hrs. Avg. 0.380 ft. per hr.
Volume 63,100 cu. ft. Surface (S) 6600 sq. ft.	Volume 44,400 cu. ft. Surface (S) 5110 sq. ft.			
*4200 cu. ft. per hr.	2200 contraction 2400 liq. disch. ——— *4600 cu. ft. per hr.	Liquid discharge rate *4750 cu. ft. per hr.	Liquid charging rate 813 cu. ft. per hr.	Liquid charging rate 740 cu. ft. hr.
22,750 cu. ft. per hr.	17,600 cu. ft. per hr.			
9.5 lbs. per sq. in.	9.5 lbs. per sq. in.	8.7 lbs. per sq. in.	11.3 lbs. per sq. in.	12.6 lbs. per sq. in.
Clear and sunny all day.	Cloudy with intermittent rain all day.	Light rain all day.	Weak sun all day.	Blanket of snow on tank partly melted by a weak sun.
	Contraction was due to a sudden shower during first 30 min.	Contraction due to temperature drop is small enough to be neglected.	Vaporization promoted by turbulence and contained air caused larger discharge.	Out breathing is again about five times greater than displacement.

*Discrepancy between observed breathing rates and proportional rates of volume change is considered largely due to the pressure drop and lag in the 600 ft. long, 8-in. diameter vent line. (It is also possible that the liquid seal may have been giving partial relief.) Further, although the maximum recorded vapor flows were corrected to 60° F., the maxima at flowing conditions were not materially larger than the corrected flows.


SUDDEN HAIL STORM (DURATION - 15 MIN.)
MAXIMUM RATE (CU. FT. PER HR.)
MAXIMUM RATE (CU. FT. PER HR.-4300) AT THIS POINT TANK SEAL BLOWN
VOLUME IN TOTAL CU. FT. PER DAY AT 60°F.-SP GR. 1.0
AV. RATE CU. FT. PER HR. VAPOR AIR MIXTURE AT 60°F.-SP GR. 1.0
SPECIFIC GRAVITY OF VAPOR AIR
LIQUID LEVEL
TEMPERATURE - DEGREES FAHR.
4-7
4-8
4-9
4-10-40

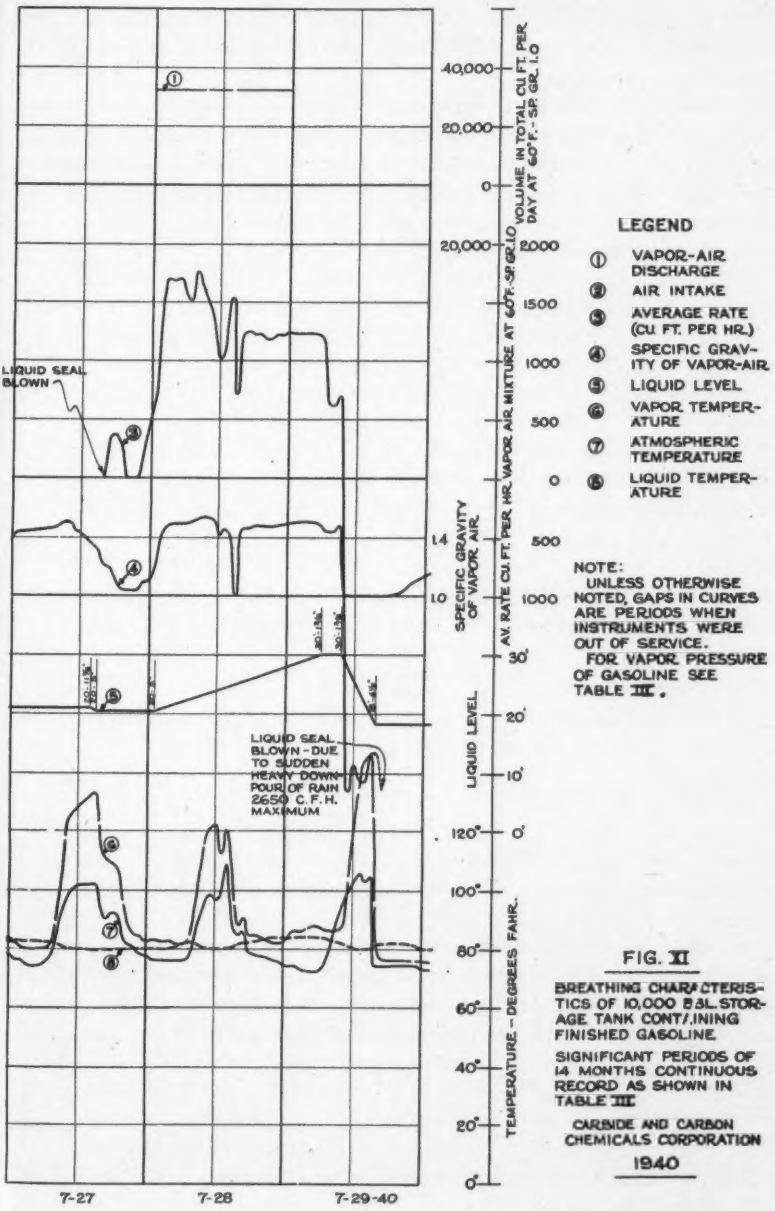


FIG. XI

BREATHING CHARACTERISTICS OF 10,000 B.B.L. STORAGE TANK CONTAINING FINISHED GASOLINE.

SIGNIFICANT PERIODS OF 14 MONTHS CONTINUOUS RECORD AS SHOWN IN TABLE III.

CARBIDE AND CARBON CHEMICALS CORPORATION

1940

Rates of venting, specific gravities of the vapors, vapor pressures, liquid levels, liquid temperatures, vapor temperatures, and atmospheric temperatures were measured and recorded.

From the standpoint of emergency venting, atmospheric tanks (usually large) present a separate problem because of the very low safe working pressure (about 3 in. water internal), the relatively large vapor space, the lessened possibility of complete envelopment in flame, and the lengthened (time) exposure required to produce maximum vaporization. The effect of the low safe working pressure and the large vapor space is such as to result in calculated relief areas which are impractical because of the unreasonably large sizes and because the maximum possible vapor flows will not be realized due principally to the large volumes of liquid involved. The lessened probability of complete envelopment in flame and the longer time required to produce vaporization are the basis of reasonable assumptions which result in more economical designs.

Maximum normal breathing was found to be that due to thermal contraction during a hailstorm. A temperature drop of 41° F. (average) in 20 minutes was observed within the tank vapor space. Some of the significant data obtained on breathing characteristics are illustrated by Figure XI and Table III.

It was concluded that the maximum rate of normal breathing of an atmospheric (1 in. water external, 3-in. water internal pressure) storage tank is

$$Q = S/0.290 + \text{Emptying Rate} \qquad (7);$$

and that the diameter of the necessary free circular opening, in the form of a pipe connection, to pass this venting rate is

$$d = \sqrt{Q/921} \qquad (8)$$

where Q and Emptying Rate are in cu. ft. of air per hr. at 68° F. and atmospheric pressure, S is the area of the tank roof and shell in sq. ft., and d is in inches.

When the volatile, liquid contents of a vessel are absorbing heat at the rate of 20,000 B.t.u. per hr. per sq. ft. of wetted surface exposed, the required inside diameter of the relief connection to limit internal pressure (not to exceed 0.50 lb. per sq. in. gage) to a specified maximum is

$$d = \sqrt{\frac{0.913\ S_W}{\sqrt{P(P+14.7)}}} \qquad (9)$$

in which d is in inches, S_W is wetted surface in sq. ft., and P is pressure in lbs. per sq. in. gage.

For vessels exposed to fire in gas service only at pressures not to exceed 0.50 lb. per sq. in. gage, the necessary diameter of the relief connection is

$$d = \sqrt{\frac{0.0407\ S}{\sqrt{P}}} \tag{10}$$

in which d is in inches, S is the surface of roof and shell exposed in sq. ft., and P is the relieving pressure in lbs. per sq. in. gage.

The Theory and Method.

The theory and method are described in Part Two. The physical conditions (pressure, temperature, and relative size) are merely different, necessitating the use of a different orifice equation and a different value for the contents factor. For this range of pressure a single numerical value of the contents factor for liquids of 0.136 is satisfactory and simplifies computations.

In the case of normal venting, the rate of contraction (rather than expansion), based on observed conditions, was equated to the relief capacity. The contained vapors, as before, were assumed to be gases, and a favorable comparison resulted between measured breathing rates and those computed by the gas law.

After determining the diameter of the relief area as outlined above, the relief capacity may be calculated by using the diameter in any one of the following orifice equations as the case may require. The relief apparatus may then be chosen of a capacity, based on approved flow test, to pass this calculated rate.

$$W = 405\ d^2 \sqrt{\frac{MP(P + 14.7)}{T}} \text{ lb. per hr. of vapor.} \tag{11}$$

$$Q = 156{,}000\ d^2 \sqrt{\frac{P(P + 14.7)}{MT}} \text{ cu. ft. per hr. at 68° F. of free vapor.} \tag{12}$$

$$Q = 29{,}000\ d^2 \sqrt{\frac{P(P + 14.7)}{T}} \text{ cu. ft. per hr. at 68° F. of free air.} \tag{13}$$

In these d is in inches, M is the molecular weight, T is the flowing temperature in degrees Fahrenheit absolute, and P is the relieving pressure in lbs. per sq. in. gage. For conditions of fire exposure, T is the normal boiling point of the liquid contents. For vessels in gas service, T is the temperature (absolute) at the relieving pressure; T may be computed by the gas law, $T/P = T'/P'$, when the initial temperature and pressure conditions and the safe relieving pressure are known. (These temperature figures are approximate, but are on the safe side.)

The Time Element.

The time required for the liquid contents of a steel vessel when exposed to intense fire to reach the boiling point or a specified average temperature

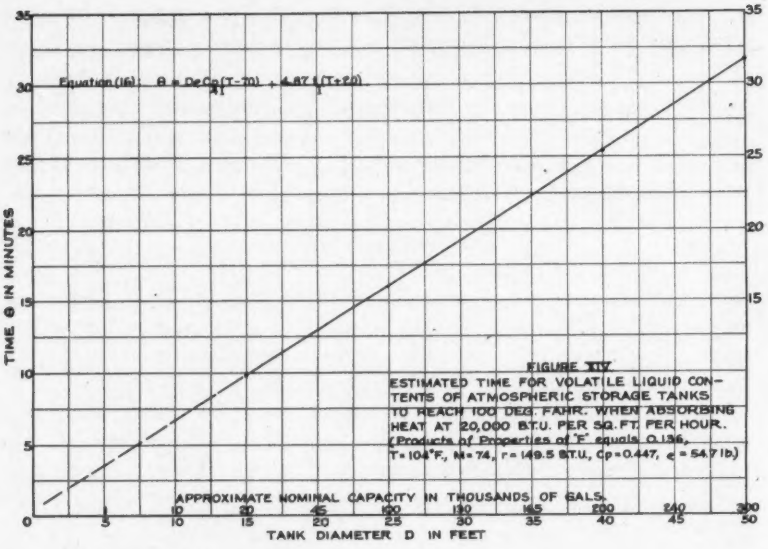

Equation (16) θ = VρCp(T-70) / AI + 4.87 t(T+20) / I
TIME θ IN MINUTES
APPROXIMATE NOMINAL CAPACITY IN THOUSANDS OF GALS.
TANK DIAMETER D IN FEET

FIGURE XIV.
ESTIMATED TIME FOR VOLATILE LIQUID CONTENTS OF ATMOSPHERIC STORAGE TANKS TO REACH 100 DEG. FAHR. WHEN ABSORBING HEAT AT 20,000 B.T.U. PER SQ. FT. PER HOUR. (Products of Properties of "F" equals 0.136, T=104°F., M=74, r=149.5 B.T.U., Cp=0.447, ρ=54.7 lb.)

may be estimated by applying the equation

$$\theta = \frac{V \rho C_p (T - 70)}{I S_W} + \frac{4.87\ t\ (T + 20)}{I} \qquad (14)$$

in which θ is time in hours, V is volume of contents in cu. ft., ρ is density of contents in lbs. per cu. ft., C_p is specific heat of contents, T is the specified temperature in degrees Fahrenheit, I is the heat absorption rate in B.t.u. per hr. per sq. ft., S_W is surface wetted by liquid contents and exposed to fire in sq. ft., and t is thickness of tank wall in inches.

The time required for the liquid contents to absorb heat at any given rate is principally a function of the tank diameter. To illustrate this and the approximate time required for contents to reach 100° F. at the observed heat rate, Figure 14 is shown. The tanks were assumed to be nominally full and of dimensions conforming to many tanks being used at this time. Calculations were made employing properties of compounds having a contents factor value of 0.136, as shown on the graph. Products having such properties are about as volatile as any stored at atmospheric pressure. Under the assumed condition, a minimum time element and maximum venting rate may be expected.

The time required for an empty steel tank to reach 1100° F. in a fire of intensity I would be approximately

$$\theta = \frac{5114\ t}{0.8\ I} \text{ or } 0.320\ t \text{ for } 20{,}000 \text{ B.t.u. input rate} \qquad (15)$$

in which the terms are as above.

Modification of Calculated Relief Areas.

For clarity it is necessary to refer to Figure XIII following.

It was seen in Figure XIV that the volatile contents of a 15 ft. diameter tank (20,000 gals.) may reach 100° F. in a matter of ten minutes after being surrounded by intense fire. For this reason, the emergency venting capacities should be compatible with the observed rate (20,000 B.t.u.) of heat absorption for all tanks from the smallest through at least 15 ft. in diameter. For tanks above this diameter at these low pressures, the calculated relief areas become rapidly unreasonably large in accordance with Curves 1 and 2 on Figure XIII, but the likelihood of complete envelopment in flame becomes less and the time required to heat the contents becomes longer. With these considerations in mind, the suggested vent size, shown by Curve 3, Figure XIII, has been made to approach the 6000 B.t.u. rate at tank capacities of 100,000 gals. and larger. Curve 4, based on the 6000 B.t.u. rate, has then been gradually flattened to a maximum of 24 in. diameter relief size at 300,000 gals. capacity. The suggested vent size, Curve 3, then incorporates a rate of heat absorption of 5000 B.t.u. at 300,000 gals. capacity, which gradually reduces to 2300 B.t.u. per hr. per sq. ft. at 1,000,000 gals. capacity. For large tanks, the proposed vent size amounts to an increase in diameter of from 20.5 to 24 in.

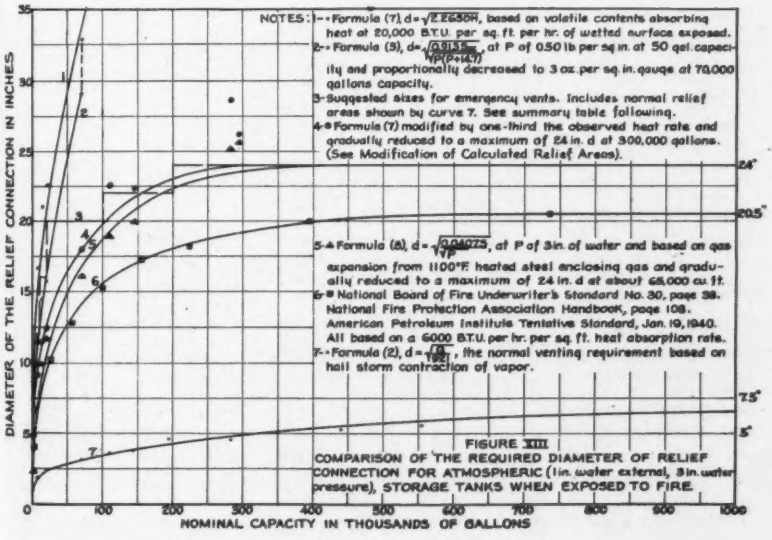

NOTES:
1- Formula (7), $d=\sqrt{2.2635H}$, based on volatile contents absorbing heat at 20,000 B.T.U. per sq. ft. per hr. of wetted surface exposed.
2- Formula (5), $d=\sqrt{\frac{(3.1)(1.5)}{\sqrt{P}(P+14.7)}}$, at P of 0.50 lb per sq in. at 50 gal. capacity and proportionally decreased to 3 oz. per sq. in. gauge at 70,000 gallons capacity.
3- Suggested sizes for emergency vents. Includes normal relief areas shown by curve 7. See summary table following.
4- Formula (7) modified by one-third the observed heat rate and gradually reduced to a maximum of 24 in. d at 300,000 gallons. (See Modification of Calculated Relief Areas).
5- Formula (8), $d=\sqrt{\frac{0.04073}{\sqrt{P}}}$, at P of 3 in. of water and based on gas expansion from 1100°F heated steel enclosing gas and gradually reduced to a maximum of 24 in. d at about 65,000 cu. ft.
6- National Board of Fire Underwriter's Standard No. 30, page 38. National Fire Protection Association Handbook, page 108. American Petroleum Institute Tentative Standard, Jan. 19, 1940. All based on a 6000 B.T.U. per hr. per sq. ft. heat absorption rate.
7- Formula (2), $d=\sqrt{\frac{V}{192}}$, the normal venting requirement based on hail storm contraction of vapor.
24"
20.5"
7.5"
5"
DIAMETER OF THE RELIEF CONNECTION IN INCHES
NOMINAL CAPACITY IN THOUSANDS OF GALLONS
0
100
200
300
400
500
600
700
800
900
1000
5
10
15
20
25
30
35

FIGURE XIII

COMPARISON OF THE REQUIRED DIAMETER OF RELIEF CONNECTION FOR ATMOSPHERIC (1 in. water external, 3 in. water pressure), STORAGE TANKS WHEN EXPOSED TO FIRE.

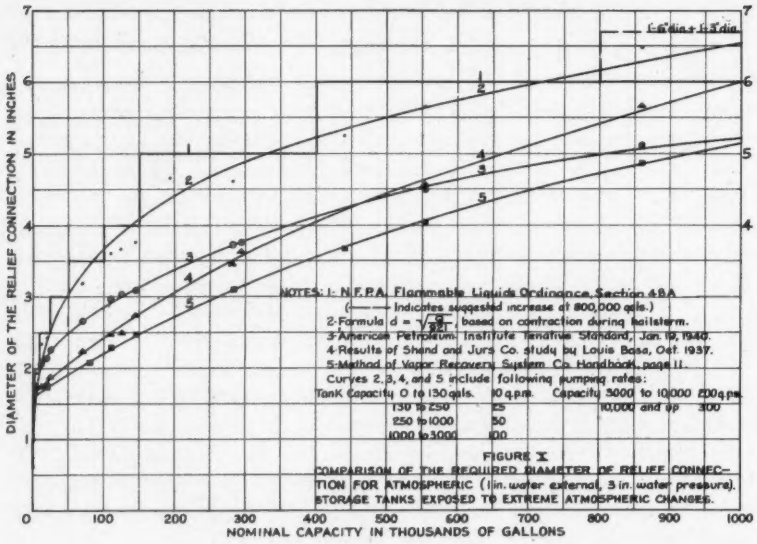

DIAMETER OF THE RELIEF CONNECTION IN INCHES
NOMINAL CAPACITY IN THOUSANDS OF GALLONS
NOTES: 1- N.F.P.A. Flammable Liquids Ordinance, Section 4 B A
(——— Indicates suggested increase at 800,000 gals.)
2- Formula d = √Q/37.1, based on contraction during hailstorm.
3- American Petroleum Institute Tentative Standard, Jan. 19, 1940.
4- Results of Shand and Jurs Co. study by Louis Base, Oct. 1937.
5- Method of Vapor Recovery System Co. Handbook, page 11.
Curves 2, 3, 4, and 5 include following pumping rates:
Tank Capacity 0 to 130 gals. 10 g.p.m. Capacity 5000 to 10,000 200 g.p.m.
130 to 250 25 10,000 and up 300
250 to 1000 50
1000 to 3000 100

FIGURE X

COMPARISON OF THE REQUIRED DIAMETER OF RELIEF CONNECTION FOR ATMOSPHERIC (1 in. water external, 3 in. water pressure). STORAGE TANKS EXPOSED TO EXTREME ATMOSPHERIC CHANGES.

SUGGESTED VENTING FOR ATMOSPHERIC STORAGE TANKS.

Tank Capacity (Gallons)	Relief Size (I.P. Size) Normal	Emergency	Minimum Capacity (cu. ft. air per hr. at 60° F. and atmos. pressure) [c] Normal at 1 in. water press.)	Emergency (at 3-in. water press.)
50	.....	2-in. vent	.....	6,150
50 to 100.....	.....	3-in. vent	.....	13,400
100 to 300.....	.....	4-in. vent	.....	24,600
300 to 1000.....	.....	6-in. vent	.....	55,400
1000 to 2000.....	1½-in. vent	8-in. cover	1,920	98,500
2000 to 4000.....	2-in. vent	10-in. cover	2,805	153,800
4000 to 10,000.....	2-in. vent	12-in. cover	3,660	221,500
10,000 to 20,000.....	3-in. vent	16-in. cover	6,180	394,000
20,000 to 50,000.....	3-in. vent	20-in. cover	8,230	615,500
50,000 to 100,000.....	4-in. vent	20-in. cover	12,500	615,500
100,000 to 150,000.....	4-in. vent	22-in. cover[d]	14,620	744,000
150,000 to 200,000.....	1 4-in., 1 3-in. vents[a]	22-in. cover[d]	18,100	744,000
200,000 to 400,000.....	1 4-in., 1 3-in. vents[a]	24-in. cover	22,820	886,000
400,000 to 800,000.....	6-in. vent	24-in. cover	32,900	886,000
800,000 to 1,100,000...	1 6-in., 1 3-in. vents	24-in. cover	41,100	886,000
1,100,000 to 1,300,000..	1 6-in., 1 4-in. vents[b]	24-in. cover	47,500	886,000
1,300,000 to 1,800,000..	8-in. vent	24-in. cover	58,450	886,000
1,800,000 to 2,000,000..	2 6-in. vents	24-in. cover	65,800	886,000

[a] Although one 6-in. may be cheaper, the two units have the advantage of multipl devices.

[b] Although one 8-in. may be cheaper, the two units have the advantage of multiple devices.

[c] To be used for selection of the normal relief devices. This capacity is included in that for the emergency requirement.

[d] This is not a standard pipe size.

Conclusion, Part Three.

In order that the proposed vent sizes (page 152) may be compared with existing knowledge, Figures X and XIII are shown (pages 151, 152). It is interesting to note that a contained gas or vapor at these low pressures will expand when in relatively large proportions, as in empty atmospheric tanks, and when exposed to tank walls heated at 1100° F. by external fire, at a calculated rate nearly equivalent to the vaporization rate of volatiles as denoted by the relation between Curves 4 and 5 on Figure XIII.

Study of these figures, practical experience with present-day venting apparatus, and consideration for economy led to the venting requirements listed in the table following.

Flammability of Vapor-Air Mixtures in Tank.

Although not directly related to the subject, the data collected on the flammability of the vapor-air mixture in the 440,000-gal. gasoline tank were of interest.

For the most part (except for three months) the combustible-gas recorder operated in connection with the vent header at a point near its outlet. Flammable mixtures were present there at frequent intervals in an irregular pattern which was no doubt due to the lag in, and large volume of, the 600 ft. long header. During June, July and August, 1940, the combustible-vapor recorder operated directly in connection with the tank. It was found that explosive mixtures were present less frequently but for longer periods, ranging up to 30 hours. In all, the tank vapors were within the flammable range 5 per cent of the time, and "too rich to burn" 95 per cent of the time. The vapor-air mixtures when combustible were never at the lower limit, the gasoline content ranging from 2 to 53 per cent by volume, as based on laboratory analyses. Flammable limits of gasoline vapor-air mixtures are about 1 to 6½ per cent by volume.

In the recorded periods (seven in number) when the vapors within the tank were flammable, in every case (except one of 45 min. on June 17) the combustible mixture was produced by a combination of emptying and falling temperature. The exception was caused by a momentary in-breathing when a shower occurred while the vapors were warm (between 9 and 10 A.M.).

The use of flash arresters or inert-gas systems with atmospheric storage tanks containing volatile flammable liquids appears warranted by these observations.

Three Defense Plant Fires.

By J. T. W. Babcock,
Factory Insurance Association (Member N.F.P.A.),
Western Regional Office.

Three interesting fires which have occurred in middlewestern defense plants during the past summer involve an aggregate loss of over one million dollars and serious interruptions to production of essential war materials. While occurring in widely separated localities in entirely different manufacturing occupancies, they were all similar in certain phases and present most important lessons which, if observed elsewhere, should have a most important influence on maintaining the continuity of production in war plants.

The three plants in Marysville, Michigan; Memphis, Tennessee; and Wyandotte, Michigan, were all owned by the Defense Plant Corporation, a U. S. Government agency, and operated by private companies on war production contracts. The operators in each case appreciated the importance of fire safety and endeavored to take appropriate measures to prevent interruption of production by fire or explosion. Government restrictions, however, prevented in two cases the installation of automatic sprinklers which had been recommended to protect the plants, and in the third case dictated the use of combustible construction for a building which should clearly have been of noncombustible construction according to recognized standards of fire safety. The neglect of fire protection in the design and construction of these plants has resulted in interference with the war effort through delays in production which outweigh many times the relatively small savings in critical material that were secured by the rejection of the original well-considered plans for fire protection.

Cottonseed Hull-Bran Storage, Memphis.

Fire on July 3, involving two of a group of buildings for the storage of cottonseed hull-bran used in furfural manufacturing, caused a loss estimated at $300,000. The plant, constructed by the Defense Plant Corporation and operated by the Q. O. Chemical Company, had recently been constructed for the manufacture of furfural, an important product used in the manufacture of synthetic rubber. The storage buildings were large-area structures of wooden construction and lacked complete automatic sprinkler protection and various safeguards which had been proposed in the original design but which had been omitted because of government restrictions.

Two large storage buildings of wooden arch roof construction, 214 feet long, 100 feet wide and 43 feet at the top of the arch, were attached together

by an overhead conveyor bridge. In the interest of economy of materials a movable belt conveyor was installed running lengthwise of the two buildings, arranged so that it could be moved from building to building and reversed in direction so as to distribute material to any part of either storage building.

Complete automatic sprinkler protection had originally been recommended. After long delays in securing approval, a partial sprinkler system was finally approved for the protection of the immediate area of the conveyors. These sprinklers were being installed at the time of the fire.

Lighting was provided by explosion-proof fixtures listed by Underwriters' Laboratories for use in Class 2, Group G locations. However, 500-watt bulbs were installed and accumulation of dust on the globe is considered a probable cause of the fire, although there is no evidence to indicate its exact origin. The use of these fixtures in a manner contrary to their intended use as regards size of bulbs and accumulation of dust had been cause for some concern prior to the fire, and it was said that orders had been given to replace the 500-watt bulbs with 300-watt bulbs, but that the change had not been made.

The fire started with a puff or dust explosion of relatively low intensity. This spread fire throughout the area and the two buildings, in which some 11,000 tons of the bran had been stored, were soon completely involved as the fire flashed through the conveyor enclosure connecting the two buildings.

The Memphis Fire Department, about two miles distant, responded promptly and with the use of plant water supplies controlled the fire and prevented its spread to other units.

Magnesium Plant, Marysville, Mich.

A large new chemical plant, erected by the Defense Plant Corporation for the manufacture of magnesium, was rapidly nearing completion, and manufacturing units were being placed in operation when, on July 13 at 2 A.M., fire started in one of the units and caused a loss of $325,000.

The plant, manufacturing magnesium by an electrolytic process, was operated by the Dow Magnesium Corporation, a company experienced in this field and well acquainted with the appropriate safeguards. The buildings involved in this fire employed extensive wooden construction in areas where, in normal times, steel would have been used. The wood was impregnated with asphalt and creosote to retard deterioration from fumes.

The fire occurred when the process in one of the units reacted violently and hot molten material came in contact with asphalt-coated woodwork. The extent of this fire may be directly attributed to the improper construction allocated by governmental authorities under the program of conservation of critical materials. The hazard of fighting fires in occupancies handling molten magnesium makes it imperative that this occupancy be located in buildings of non-combustible construction.

Although the alarm was given at once and the fire department called, the fire spread rapidly. The plant fire department, together with firemen from Marysville and Port Huron, used hose streams and eventually brought the fire under control. It is important to note that none of the pure pig magnesium which was located on the floor was in any manner damaged by the fire.

Bleaching Powder Plant, Wyandotte, Mich.

The plant of the Pennsylvania Salt Manufacturing Company, Wyandotte, Mich., had recently undertaken the production of bleaching powder for the government, utilizing large rotary kilns owned by the Defense Plant Corporation. Fire on August 7 caused practically a total loss of the building housing these kilns with damage estimated at $375,000 or more.

The building was a two-story structure with brick walls and wooden joisted floors and roof. The operating company, familiar with the hazard of operating such hot process equipment in a building of wooden construction, had applied for authority to install automatic sprinklers, but the application was rejected.

The exact cause of the fire is not known, but may have been due to an oxyacetylene welding operation which had been finished at 6:30 P.M.; the fire was discovered by employees working in adjacent buildings about three hours later. The Wyandotte Fire Department was called and, together with the plant fire brigade, used ten hose streams, which were successful only in preventing the fire from spreading to other buildings.

Soybean Plant Fire Record.

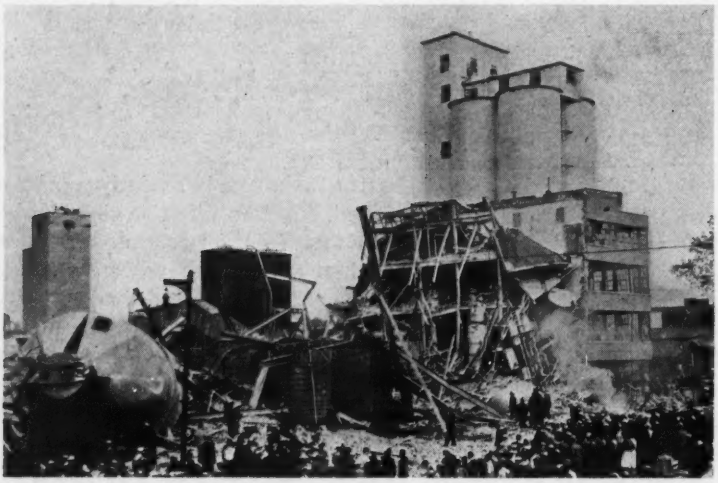
By Warren Y. Kimball,
N.F.P.A. Engineer.

During the past few years soybeans have become increasingly popular as a source of both human and animal food, fertilizer, vegetable oil and other products. With the wartime shortage of meat foods for human consumption, the United States Department of Agriculture and other agencies are encouraging an extensive increase in the production of food products derived from soybeans, because this crop is rich in protein content. Very recently a large bakery concern has announced that all of its white bread will henceforth contain added soybean flour to help combat protein deficiency in the average diet.

From a somewhat limited experience with soybean processing plants and their products as a fire hazard, it is clearly evident that many serious fires may be expected unless the hazards are recognized and adequately guarded against. Briefly, it may be stated that a study of the following typical fires taken from the files of the N.F.P.A. Department of Fire Record, shows that soybeans and their products are easily ignited, and present fires that are difficult and troublesome to handle. A large proportion of these fires involved soybean oil extraction plants. Soybean oil has a flash point of about 540° F. It is decidedly subject to spontaneous ignition. The soybean meal cake left after the oil is extracted is very troublesome once ignited. Fire reports tell of the formation of hot clinkers that could not readily be extinguished by any normal means. It is indicated that pouring water on such fires may result in violent steam explosions.

Much of the soybean oil extracting machinery and processes are somewhat complicated and are subject to numerous fire hazards. Several of the earlier fires reported in this record were the result of explosions of escaping hexane vapors in plants where the soybean oil was obtained by a solvent process. Most of the more recent fires in soybean oil mills involved the so-called expeller process by which soybeans are crushed or ground in mills, are heated usually by steam-heated equipment, pass through extractors, and then pass through coolers. Several of the fires were due to improper arrangement or operation of processes involving the heating of soybeans in process of having oil extracted. Spontaneous ignition and dust explosions each caused at least one important fire in this comparatively brief record.

A considerable proportion of the reports included emphasized that the plants involved had not been constructed for use as soybean processing or extraction, but had been converted to such use without much consideration having been given to the increased fire hazards involved. Few, if any, of the



International.

Wreckage of the Glidden soybean plant after the explosion on October 7, 1935, in which eleven men were killed and forty-five injured.

plants had any adequate first aid fire protection, and most lacked sprinkler protection. In one case the sprinkler equipment in the original plant had not been extended to cover the soybean processing areas. In a number of cases the plants were located in sections where public protection was either lacking or was seriously deficient. A study of the fires in this record leads to the conclusion that standard sprinkler protection backed by adequate water supplies would do much to safeguard this industry. Greater attention should also be given to proper cut-offs by means of standard fire walls and fire doors. A large proportion of the fires extended to involve all sections of the plant because of sub-standard fire divisions.

October 7, 1935, Chicago, Illinois. Soybean Processing Plant.

An explosion which caused the death of 11 men and injured 45 others occurred at the Glidden Soya Products, Inc., processing plant operated for the production of soybean oil, meal, protein and lecithin. The plant, which had a capacity of about 4000 bushels of beans a day, was almost totally destroyed with a loss of approximately $600,000.

The property consisted of several new buildings and old buildings which had been recently remodeled. Reports indicate that all structures were well maintained and in good condition. Prior to the explosion the extraction unit had been shut down for about a month, awaiting a new crop of beans. This time had been used in making repairs and improvements.

Principal buildings in the section affected by the explosion were the elevator, bean preparation building, extraction building, lecithin building, protein building, tank building, and the warehouse.

The southwest corner of the Glidden Company soybean plant in Chicago as it appeared from the top of the elevator tanks following the explosion.

The elevator, a modern concrete and steel storage plant, similar to a wheat or corn-handling plant, consisted of a workhouse and four large cylindrical tanks 100 feet high. Other buildings were of 4- to 6-story brick and steel construction, except that the tank building was open for its full height of 50 feet. Floors as well as fire walls between the buildings were pierced by a few openings where equipment extended through the wall or floor. Most wall openings were protected by fire doors.

Description of Process.

At the elevator, beans were unloaded from cars and stored or elevated to the top of the house for transfer to the processing part of the plant. From the elevator the beans passed through an 8-in. pipe by gravity to the top floor of the bean preparation building. Here they passed over separators, through scales and up an elevator leg into a tank over a cracking roll, which cracked the beans into 3 or 4 pieces. From the cracking roll the stock passed through a drier or temperer to the flaking roll. The flakes, ⅜ in. to ¾ in. in diameter, fell to a belt conveyor, which carried them to a second elevator leg. From the top of this leg the stock flowed through a spout which passed through the brick wall into the extraction room, where a belt conveyor carried it to the top of the extraction tower. This tower, a U-shaped apparatus, was about 28 ft. high, with tubes 39 in. in diameter. Screw conveyors with perforated flights operated downward on the entrance side across the bottom and upward on the discharge side. Hexane was pumped to the intake side of the tower, and the oil and

hexane mixture was drawn off and piped to the distilling column, where the hexane was recovered and put back into the process.

The extracted flakes from the discharge side of the extraction tower passed through a spout to the drier, a series of steam-heated drums through which the material was carried back and forth and finally discharged into a screw conveyor on the first floor. This conveyor, set at an incline, carried the stock to the cooler, and the discharge from the cooler passed through the wall into the bean preparation building. Here it was elevated and dropped into an air stream, which carried it through an overhead pipe line to the bagging or warehouse section at the northwest corner of the plant, where it was caught in a cyclone and discharged to a packing bin.

In the lecithin plant, oil separated from the hexane at the distilling tower was processed to obtain lecithin, a product used in candy and chocolate coatings. The oil is used as an edible product and also in the manufacture of paints.

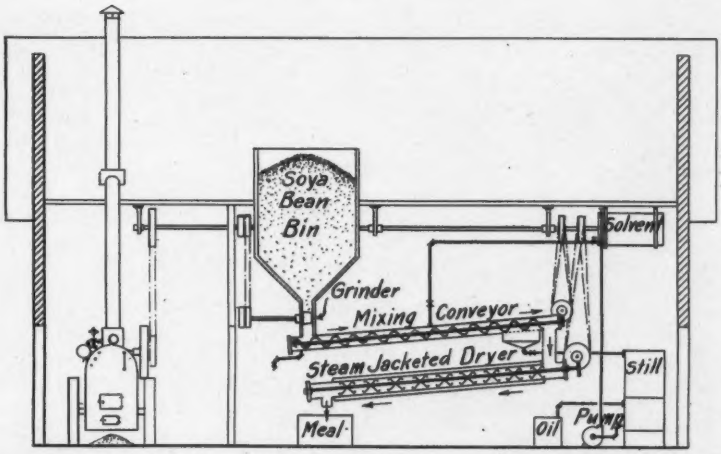
In the newly remodeled end of the plant, known as the protein building, the extracted flakes, received either directly through a roof conveyor from the bean preparation building or in sacks after being bagged at the warehouse, were treated to produce protein in a powdered form similar to casein. In the process, batches of flakes or meal were mixed with warm water in slurry tanks in the south end of the protein building and then pumped into one of the south six tanks in the tank building. In these tanks the material was treated and agitated and pumped back into the protein building, where the liquid was drained off and the residue dried. When discharged from the drier it was elevated and dropped into the meal bin on the fourth floor, where it was bagged for shipment as meal.

The liquor from the above process was pumped to filter presses on the sixth floor, and the press cake from these presses was fed into a drier at the north end of the protein building. After being dried in the oil burner heated columns of the drier, the product was screened and packed for shipment.

Story of the Explosion.

The new crop had just become available and the extraction unit had started operating again on the morning that the explosion occurred. About three hours after the plant started, employees detected an odor of gas. One of the foremen in the protein department was on his way to report this to the manager when the explosion occurred.

From evidence assembled by Dr. David J. Price of the U. S. Department of Agriculture (President of the N.F.P.A.) and Hylton R. Brown, at that time also in the Department of Agriculture and now with the U. S. Bureau of Mines, it is believed that gas from the extraction building passed into the tank building at or near the top of the fire wall separating the two units, or possibly through the pipe carrying condenser water into the tank building. Due to cool weather, windows were closed and there was little or no ventilation in the tank building. Probably a large pocket of gas accumulated at that point. The gas could have been ignited when the flash occurred at the flaking roll. In fact it is quite likely that the burns received by an employee at the flaking roll were received in a mild or minor dust explosion at that point. This flash, passing through the doorway between the bean preparation building and the tank building, could have been the source of ignition for the main explosion. It is also possible that gas was present in the bean preparation building as



Soybean extraction unit at Momence, Illinois. No original drawings were available and this sketch is based upon evidence obtained after the explosion.

well as in the tank building, and that the motor circuit breaker opening or a flash at the roll provided a direct ignition for the gas and air mixture.

(See N.F.P.A. QUARTERLY for January, 1936, page 233.)

October 22, 1935, Momence, Illinois. Rural Soybean Oil Plant.

An explosion in the soybean oil extraction unit of this plant killed the owner, Varnum Parish, Jr., and his assistant, and injured two other persons. The unit was one of the first installations of this type on a rural community basis in Illinois. The blast occurred about six hours after the plant had started its initial operation.

After graduation from a university in the Middle West during June of 1935, Varnum Parish, Jr., had devoted his attention to the possibility of installing a unit for extraction of oil from soybeans and the production of soybean meal for cattle feed. The equipment was made in a local iron works in a near-by town and was installed in a building formerly used as a chicken hatchery. Dr. David J. Price of the U. S. Department of Agriculture reported that as near as could be determined from an examination of the wrecked equipment, the process was carried out as follows:

The soybeans were dropped from a hopper on the floor above into a vertical pipe in which a small grinding mill was installed. This mill, operated by a belt drive, crushed the beans into meal. The ground product dropped into a pipe about 18 inches in diameter, inclined upward at about 10 to 15 degrees from horizontal, in which a spiral conveyor was installed.

The solvent, a commercial form of hexane, was drawn from a 55-gallon drum on the second floor and pumped into the extraction unit above. The hexane solvent entered the pipe, came in contact with the soybean meal as it was carried up by spiral conveyor, and extracted the oil. The oil was carried off to receiving tanks and the solvent recovered. The oil-free meal dropped

Wreckage of the soybean extraction unit, Mömence, Illinois, after the explosion on October 22, 1935, in which two men were killed and two were injured.

into another pipe set at about the same angle and located directly underneath the extraction pipe. In this pipe, which was steam-jacketed, the residual solvent was driven off as the meal passed through. The meal was discharged into a container. The steam for the soybean meal drier and other purposes was supplied by a tractor engine boiler installed in an adjoining room.

Story of the Explosion.

The explosion occurred about an hour after the afternoon run was started. A short time before a local man arrived to observe the operation of the plant. He called the operators' attention to the odor of gas. About ten minutes later the explosion took place. This observer was standing near the end of the unit near the boiler room door, and was blown out through a near-by door, receiving burns. He saw the fire flash from the firebox in the boiler room and heard a second explosion, which blew both operators out of a door at the other end of the building.

From investigation, it appears evident that hexane vapors were escaping from the extraction unit. The heavy vapors settling in the extraction room passed through the open door to the boiler room, where they ignited at the firebox and flashed back into the extraction room, where the so-called second explosion occurred. (See N.F.P.A. QUARTERLY for January, 1936, page 240.)

January 22, 1937, Des Moines, Iowa. Soybean Meal Storage Tank.

A fire, believed due to spontaneous ignition, caused a large loss of soybean meal cake stored in an outside vertical steel tank at a plant of the Spencer-Kellogg and Sons, Inc. The fire continued for a number of days, and

on March 12 an explosion wrecked the top of the tank and badly damaged the roof of an adjoining tank. Complete extinguishment and removal of contents was not completed until March 27, or more than two months after the start of the fire.

Approximately 300 tons of meal cake was reported to have been in the tank when the fire was discovered. About one-third of this amount was withdrawn and ground for feed or fertilizer prior to February 2nd, when further withdrawal was considered unsafe and an attempt was made to smother the fire and cool the contents by using carbon dioxide ice. This was continued until February 23rd, when it was stopped because the owners did not think the carbon dioxide was effective. Meanwhile fire developed in a pile of several tons of cake in an adjoining tank. This fire was not extinguished until February 22nd. The operations to control the second fire affected the original fire adversely.

Following February 23rd, several attempts were made to withdraw contents of the tank through holes cut in the sides without attempting to extinguish the fire. Finally, on the afternoon of March 12th, three severe explosions occurred inside the tank at about two-hour intervals. The last one wrecked the top of the tank and water could then be used freely on the burning contents. Removal of the contents was difficult, but the work was completed on March 27th.

The tank involved, known as No. 4, was one of a group of four vertical steel tanks built directly on the ground. Contents are normally removed through holes in the flat bottoms to conveyor tunnels which lead to the basement of the mill building. The space between the tanks was enclosed with steel plates to form a fifth storage tank. The four main tanks were 25 feet in diameter, 60 feet high, with conical metal tops. Each tank had two vent pipes and two tightly fitted metal covers.

Tank No. 4 was filled to about 10 feet from the top when smoke was first noticed. All of the cake had been made recently, after a new continuous process oil expeller system had been put into service. The cracked beans were heated in a steam drier before the oil was expelled. The cake reached the top of the storage tank at about 160° F., and the moisture content was less than three per cent. The cake was later ground and sacked for feed.

The experience from this fire indicates the great care needed to prevent spontaneous ignition of soybean meal cake produced by this process. The high temperature of the cake when the tank was filled probably contributed to the start of the fire. Smaller units of storage and tank construction to permit rapid dumping of contents seem to offer the most practical method of quickly controlling a fire in this material. Most of the difficulties encountered during this fire resulted from attempts to remove the contents through openings that were too small for rapid removal of contents but that were large enough to admit large volumes of air. It is fortunate that the tank was of steel construction and was not inside the building.

The usual methods of extinguishing fire are said to be of little value when active fire develops in this soybean cake. Water does not penetrate more than a few inches below the surface. In this fire, smoke continued to rise when the pile was almost submerged. The use of spray was ineffectual and the added moisture may have been harmful. The dense pasty clinker which formed from

the burning meal could scarcely be broken up. Because of the strong draft, intense fire developed when burning clinker became lodged at a tank opening. The use of water for flooding such a fire is not advisable, because the material swells into a doughy mass when wet and violent steam explosions are caused by water trickling into fire pockets. It is believed that the contents of the tank might have been saved had the first attempt to use carbon dioxide gas been continued without trying to remove any of the contents. A tight tank is essential to any rapid headway in smothering such a fire and the carbon dioxide escaped as the tank was being emptied.

May 15, 1939, Toledo, Ohio. Soybean Oil Extraction Plant.

This plant, occupied by the Archer-Daniels-Midland Company, had recently been remodeled for the installation of new machinery to extract soybean oil by the expeller method. Construction changes included the erection of two frame iron-clad roof houses, 1 equals 3 and 1 equals 4 stories in height. These were 17 by 45 and 17 by 50 feet in size. Sprinklers had not been installed in the roof houses as the work was to be done by plant mechanics when convenient.

The fire originated in a metal stack from driers which evidently had been coated with residue which ignited spontaneously. Sparks from the burning stack set fire to the unsprinklered roof areas, which were destroyed. Only slight damage was done to areas under sprinkler protection. Approximately 3000 bushels of soybeans were damaged, together with 1000 gallons of oil. The loss was $20,000.

August 24, 1939, Buffalo, N. Y. Soybean Cake Cooler.

Fire was discovered in the second floor of Mill Building A-3, in the Spencer-Kellogg and Sons, Inc., soybean cake cooler room and vent stack. The blaze was discovered by employees at 1.50 A.M. While the cause was not definitely established, it may have been due to some loose abrasive material being churned around in the mechanical cooler; or it may have been due to spontaneous heating of the soybean cake or dust which comes from the cooler at 215 to 230° F.

The fire was held in check by four sprinklers, but was mainly in the vent stack, the cooler, the conveyor and the hopper leading from the cooler to the automatic scale. The loss was estimated at $500 by the fire department.

The soybeans are crushed or ground in mills on the first floor of the plant. Then they are heated in steam heaters on the second floor to perhaps 240° F. and before passing through the screw extractors are again heated to about 260° F. After extraction, the chips of cake about as large as bent silver dollars reach the mechanical cooler. From the cooler the cake passes at about 150° F. to a hopper on the floor above, and then through a mechanical scale on its way to the outside storage bin, which it reaches at a temperature of about 130° F. The fire occurred in the 20-inch natural draft vent pipe from the cooler, and also involved the cooler. It also reached the hopper and automatic scale, but no charred material reached the storage bins.

October 19, 1939, Fort Dodge, Iowa. Soybean Oil Mill.

Fire of undetermined origin caused total destruction of the soybean oil extraction plant and warehouse of the Plymouth Processing Mills with a loss

of approximately $140,000. The plant had been engaged in soybean oil extraction by the expeller process since May, 1936. The one-half story mill building of ordinary construction was formerly used for brick and tile manufacture. The owners had converted the plant for soybean oil extraction by the installation of steam-heated oil expelling machinery. The equipment included a working bin of wooden construction with a capacity for 10,000 bushels of beans. The mill section communicated with the 3½-story warehouse section of ordinary construction, which was 250 feet long by 80 feet wide. There were unprotected conveyor and chute openings in the brick wall between these buildings. Door openings were protected by non-standard metal-clad doors

Employees discovered the fire at 3:24 P.M. It is believed that sparks from a brush fire outside the building had blown to a monitor on the roof of the warehouse. An accumulation of dust caused the fire to spread rapidly. Dropping embers ignited 70,000 bushels of soybeans in the storage bin. Employees connected all of the standpipe hose in the building into one line, but the height of the roof and poor city water pressure in the vicinity made the stream ineffective. The fire department upon arrival pumped into the standpipe system, but embers had already ignited beans in the bin beneath the slatted floor. Fire spread rapidly across the surface of the beans, making dense smoke. A fire captain was burned in making his escape from the fast spreading fire. Inadequate water supplies made it impossible to check the spread of the fire to adjoining sections of the plant.

January 2, 1940, Marion, Ohio. Soybean Cake Storage.

A fire of uncertain origin started in a soya cake bin on the second floor of the soybean oil plant of Old Fort Mills, Inc. It is thought that some hot metal or soya cake from the welding of a screw conveyor in the basement may have been elevated to the bin and after smouldering for hours burst into flame. There is also a slight possibility that a spark from the boiler stack may have ignited dust on the bin ventilator, causing sparks to drop into the bin.

This non-sprinklered plant was of moderate size and employed about 10 hands on each of the three shifts daily. About 2500 bushels of soybeans were processed per day, producing 2000 gallons of oil and 50 tons of mixed feed. The soybean storage capacity had been recently increased to 650,000 bushels by the addition of eight reinforced concrete storage bins. The mill building was of steel construction with wooden floors and part wooden roof. The elevator and storage tanks were of fire-resistive construction.

On the day before the fire, trouble had been experienced with an all-metal screw conveyor in the basement. This conveyor led through the soya cake cooler to an all-steel elevator leg which brought the cake to a combustible bin on the second floor of the mill.

The expeller operator on his rounds discovered the fire about 4 A.M. It was already beyond the control of chemical extinguishers. The city fire department reports that there was a 16-minute delay in giving them the alarm, but with the use of four hose streams they were able to confine the fire to the second floor and roof. The fire department reported the loss at $46,900.

February 14, 1940, near Springfield, Illinois. Soybean Oil Mill.

This soybean oil mill, operating under the mechanical extraction process, was destroyed by fire with a loss of approximately $120,000. The buildings

were outside of the city and three miles from a fire station. They were owned by the Springfield Stock Yards Company. The plant, designed as a corn mill and elevator, had been rebuilt in 1932 after a severe fire in 1928. It was occupied as a feed store, feed mill and elevator. Section 1 was of brick construction and Section 2 was of incombustible construction.

The fire started in a bean drier or in its ventilating stack on the second floor of Section 1, where metal vent stacks passed through combustible floors without sufficient clearance. It is possible that the fire would have been confined to the drier if the clearance had been sufficient. When the Springfield fire department arrived the fire had considerable headway, and the one weak stream that could be obtained from a 6-inch dead-end main near by proved entirely inadequate.

October 22, 1942, Oakville, Indiana. Farmers' Elevator Company.

Fire destroyed this country grain elevator and feed mill of frame iron-clad construction. Volunteer fire departments could do little more than protect exposures due to the shortage of water. A steel tank containing soybeans located 5 feet from the elevator suffered 10 per cent damage to its contents. The total loss from the fire was $46,000, of which $26,000 was damage to stock.

November 28, 1942, Danville, Illinois. Rural Feed and Soybean Plant.

This property, operated by the Hendricks County Farm Bureau, consisted of a feed mill of frame iron-clad construction, three stories in height and a one-story brick soybean processing plant adjoining but not cut off. The fire was discovered at 1:25 A.M. on the unused third floor of the feed mill. Due to the headway of the fire, which was spread by explosions of barrels of soybean oil, the volunteer fire department devoted most of its efforts to a successful attempt to save a grain elevator twenty feet distant. The loss was $30,460.

March 31, 1943, Cairo, Illinois. Vegetable Oil Mill.

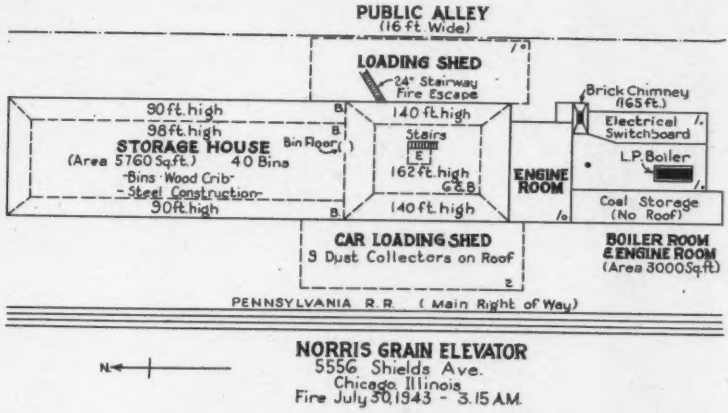
Fire originated about 4:40 A.M. in a cotton seed storage area of the Cairo Meal and Cake Company's plant. This plant included a soybean oil mill. The cause is unknown. Automatic sprinklers, on an obsolete sprinkler system, operated, but were unable to control the fire due to its rapid spread through the old wooden building, which had a high ceiling covered with lint. There are also indications that the fire pump was not in automatic service at the time of the fire. The loss has been estimated at $1,653,000, including damage to a large stock of wool in one of the warehouse structures. (See N.F.P.A. QUARTERLY for July, 1943, page 65.)

July 30, 1943, Chicago, Ill. Soybean Oil Plant and Elevator.

A dust explosion, believed to be the first on record in a soybean oil plant using the expeller process, wrecked the processing and oil extraction building and caused a fire that subsequently broke out in the storage house containing 40 grain storage bins. Three workmen were seriously injured by falling brick walls blown out by the initial explosion. The loss has been estimated at between $400,000 and $600,000. The plant was operated by the Norris Grain Company.

Description of Property.

This plant was a terminal grain elevator group consisting of a 60,000-bushel brick incombustible cleaning and storage elevator 162 feet in height,



with a 360,000 bushel frame cribbed grain tank annex. This building was of steel wall construction with grain tanks 100 feet high. An adjoining one-story and basement brick building was used as a soybean oil expressing plant. The basement of this building contained the boiler room, millwright shop, locker rooms, and office. The first floor was of 3-inch boards on unprotected steel. This floor contained the steam soybean cookers, hydraulic oil extracting presses, steam meal driers, and filter presses. About four feet below the floor was a false floor of tile on unprotected steel. This false floor contained soybean oil tanks and oil troughs. In the yard outside this building were six above-ground steel tanks having a total capacity of 47,500 gallons of soybean oil.

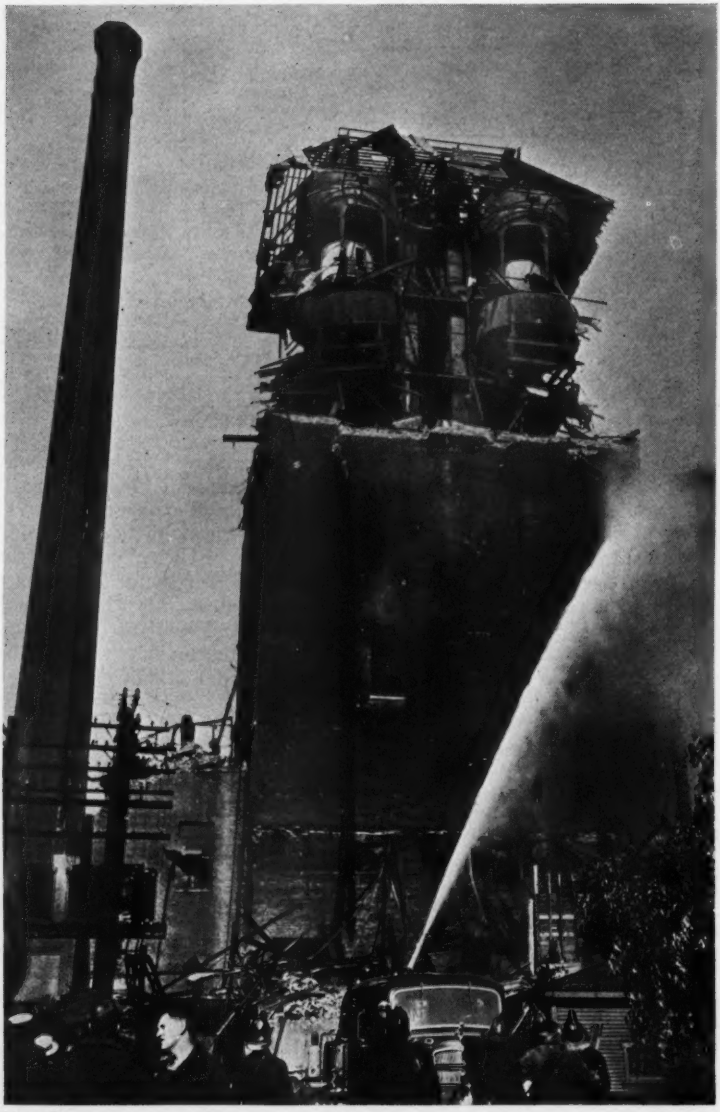
Although originally constructed as a grain elevator, this plant had been used mainly for soybeans. The soybean oil and the meal left over after the expressing process were sold in carload lots.

Story of the Fire.

The initial dust explosion occurred at 3:13 A.M. It was at first believed that the explosion occurred in the elevator, which practically demolished the cupola and blew out the upper portions of the brick walls, part of which fell upon the mill building.

A report by State Fire Marshal John H. Craig places blame for the explosion on a fan in the mill building. This fan blew the cake from a screw conveyor beneath the floor of the expeller through a duct to the elevator storage bin. However, grain elevator men consider the exact cause of the spark or ignition responsible for the dust explosion to be unknown. It is known that the elevator portion of the plant closed down about 4:00 o'clock the previous afternoon. The initial explosion threw bricks over a two-block area and rocked

Note: This report was prepared from information furnished by Chief Engineer John Plant, Chicago Fire Prevention Bureau (Member N.F.P.A. Committee on Fire Record); G. F. Butt, Secretary, John S. Metcalf Co. Grain Elevators; Dean M. Clark, Society of Grain Elevator Superintendents of North America (both Members of the N.F.P.A. Committee on Dust Explosion Hazards), and State Fire Marshal John H. Craig (Member N.F.P.A.).



Chicago Sun.

Firemen shown fighting fire which followed explosion in the Norris Grain Company's soybean plant in Chicago on July 30, 1943. This is stated to have been the first major dust explosion recorded in a soybean plant. Three workmen were killed. Note how the brick walls were blown away from the top of the plant.

Chicago Sun.

This gives a good view of the devastation caused by a dust explosion in the soybean plant of the Norris Grain Company in Chicago. Almost two hours after the explosion a major fire broke out in the soybean storage tanks adjoining the elevator. Loss from this explosion and fire has been estimated at between $400,000 and $600,000.

the neighborhood. Near-by houses were evacuated. At 5 A.M. flames broke out with great intensity in the grain storage bins. This was the first evidence of fire following the explosion. At this time the fire department sounded additional alarms, bringing 32 pieces of fire apparatus to the scene. The fire was controlled by the use of ten 2-inch nozzles mounted on two water towers, three high pressure trucks, and three squad wagons.

Damage to plant buildings and equipment has been estimated at $275,000. The loss to contents, amounting to $300,000 or more, included damage to 150,000 bushels of soybeans, 2000 bushels of corn, and 400 tons of processed soybean oil and meal.

August 2-7, 1943, Buffalo, New York. Soybean Oil Plant.

During the above period about a dozen smouldering fires occurred in cookers or driers and in the steel exhaust duct system of the expeller plant in the first floor of Mill A, Spencer-Kellogg and Sons, Inc. It is reported that soybeans had been put through this particular heating and expelling process for several months, but that prior to these fires linseed oil processing had been substituted. The setting of dampers for the ducts which exhaust the moisture from the heaters or driers should be different for the two products. Also steam pressures are not the same. It is probable that the old settings employed in previous years when flax was used exclusively were not resumed, with the

result that fires occurred. Extinguishment was accomplished by hoeing out the dust and smouldering flaxseed, and by the use of extinguishers and service hose.

August 6, 1943, Buffalo, New York. Soybean Oil Plant.

Fire occurred in one of three steam-heated driers for crushed soybeans in the second floor of Mill A, Spencer-Kellogg and Sons, Inc. This building is of frame construction covered by protected metal. Fire extended into the moisture exhaust duct and cyclones in the cupola. The fire was believed due to charring and spontaneous heating of crushed soybean dust on steam pipes in the driers, where a temperature of 350° F. is maintained. The fire was extinguished by the fire department using hose streams and scraping tools after efforts by employees to extinguish it with service hose and extinguishers proved ineffective. Six sprinklers at the ceiling operated and appeared to aid in cooling the ducts.

Several other small fires have occurred in the heater and drier systems. It appears that because of the scarcity of labor the heaters were not cleaned as frequently as formerly, and oily cake and dust had accumulated. The thermostats in the exhaust sections of the driers did not operate, but it is possible that sparks were drawn past the thermostats, which were set to operate at 500° F. Because of ample clean-out doors the fire department was readily able to cope with this fire.

Fires and Fire Losses Classified, 1942.

Continuing the practice begun six years ago of showing the distribution of the annual fire loss in the United States by cause and occupancy classes, the N.F.P.A. Department of Fire Record presents the following tables covering the year 1942. Experience of the past years shows that these estimates are widely used in fire prevention and fire protection work.

The data upon which these tables are based were obtained from twelve state fire marshals' reports for the year 1942, or the closest fiscal year thereto. Reports of these particular states were chosen because they contained the most complete classifications. While methods of reporting and tabulating fire loss figures are different in each state, it is believed that the volume of statistics from the twelve typical states included herein is sufficiently large to indicate the relative distribution of fires and fire losses for the various occupancies and causes.

Tables I to IV are tabulations made from fire marshals' reports. Table I shows the number of fires, and Table II shows the fire loss by occupancies reported for the year 1942 in the twelve states. Tables III and IV show the number of fires and losses distributed according to causes. The general classes making up both the occupancy and cause classifications were carefully chosen with regard to good practice and to classes most commonly used in the reports. Tables V to VII are recapitulations and estimates for the entire United States based upon the first four tables and adding a certain percentage to cover unreported fires and losses as explained below.

Table V is a recapitulation of the state totals presented in the foregoing tables, with columns added to show the number of fires per thousand population and the fire loss per capita. It will be observed that a total of 88,217 fires were reported in 1942 for the group of twelve states having a total population of 35,335,937 in the 1940 census. A study of the best data available indicates that this number of fires is approximately half the actual number of fires for the year, and therefore 100 per cent has been added to get the estimate for the twelve states. When the resulting figure is applied to the whole country at the population ratio, the estimated number of fires in the United States in 1942 is 665,000. This makes 5.05 fires per thousand population as compared with 5.58 in 1941 (October, 1942, QUARTERLY, page 171).

The estimated fire loss of $315,000,000 in the United States in 1942 was obtained by applying the population ratio to the total loss in the twelve states and adding 30 per cent to cover unreported losses. This figure is $10,000,000 less than 1941 and $25,000,000 more than the corresponding figure for 1940.

Table I. Number of Fires by Occupancies in Twelve States — 1942.

Occupancy	Illinois	Indiana†	Iowa	Kansas	Massachusetts	Nebraska	Ohio	Oregon*	South Dakota†	Vermont	West Virginia	Wisconsin	Total
I. Public Buildings													
Government buildings	2	4	....	8	29	6	....	15	1	3	....	18	86
Hospitals, institutions	6	3	12	....	17	1	46	....	1	5	....	25	116
Schools and colleges	67	18	10	9	25	18	52	20	10	12	5	70	316
Churches	63	30	23	16	31	15	94	16	4	4	2	73	371
Theatres, including motion pictures	28	7	13	8	15	13	55	12	5	2	1	29	188
Amusements, halls	58	35	12	....	62	5	85	....	4	3	4	52	320
II. Dwelling Occupancies													
Hotels, boarding houses	156	24	30	24	203	20	216	116	26*g*	7	3	220	1,045
Apartments, rooming houses	2,685	148	137	....	....	17	1,866	....	14	1	9	192	5,069
Dwellings	5,214	2,505	1,925	1,196*a*	4,534	1,223	10,591	3,176	390	640*d*	257	11,388	43,039
III. Mercantiles													
Office bldgs., including banks	140	27	36	....	214	47	163	....	10	2	5	63	707
Restaurants, taverns	304	67	80	....	108	61	....	22	....	3	4	358	1,007
Barber, beauty shops	16	....	6	....	9	5	....	....	....	....	1	36	73
Misc. mercantiles	1,129	238	186	325*b*	949	254	1,316	246*b*	69	63	43	786	5,604
Warehouses	90	70	67	....	122	16	351	6	....	2	11	98	833
IV. Manufacturing													
Metal workers	26	8	28	3	29	....	....	13	5	4	1	44	161
Woodworkers	7	22	5	....	11	....	....	53	1	17	....	15	131
Flour mills, elevators	55	6	30	12	....	10	....	12	7	3	....	57	192
Packing plants, stockyards	23	4	12	....	....	3	....	....	2	1	....	18	63
Bakeries	35	9	9	....	18	2	....	21	....	2	....	14	110
Laundries	32	13	11	....	26	....	59	14	2	2	2	17	178
Cleaners, tailors	35	18	13	16*c*	23	2	58	....	2	....	2	18	187
Misc. manufacturing	498	125	63	33	389	64	996	18	13	12	19	325	2,555
V. Miscellaneous													
Barns	413	236	172*d*	216*d*	157	178	365	90*f*	102*f*	....	18	616	2,563
Outbuildings	803	249	170	....	226	107	609	....	....	1	8	273	2,446
Lumber and coal yards	18	13	4	2	28	32	44	....	2	3	....	9	155
Railroads, wharves	71	17	13	11	27	6	....	1	4	....	1	115	266
Bulk oil storage, refineries	20	4	3	42*e*	....	4	....	16	3	....	....	....	92
Garages, filling stations	994	247	245	1	254	232	1,362	11	61	15	22	381	3,825
Power plants, pump houses	19	13	7	....	5	12	....	18	3	2	....	82	161
Creameries, dairies	....	9	11	....	....	4	....	15	5	....	....	60	104
Miscellaneous structures	396	20	108	24	131	13	1,781	1	1	1	....	43	2,519
Motor vehicles	1,536	347	372	223	808	91	3,252	478	100	....	58	1,284	8,549
Fires other than structures	229	97	53	242	15	91	....	1	24	....	....	1,376	2,128
Hangars and contents	....	2	....	1	1	1	....	....	5	2	....	1	13

*Number of insurance claims, not number of fires.
†Fiscal year ending June 30, 1942.
a. Does not include farm property.
b. Includes office buildings.
c. Includes cloth and textile workers.
d. Includes all farm property.
e. Includes filling stations.
f. Includes outbuildings.
g. Includes restaurants.

a. Does not include farm property.

b. Includes all farm property.

g. Includes restaurants.

Table II. Fire Loss by Occupancies in Twelve States — 1942.

Occupancy	Illinois	Indiana†	Iowa	Kansas	Massachusetts	Nebraska	Ohio	Oregon*	South Dakota†	Vermont	West Virginia	Wisconsin	Total
I. Public Buildings													
Government buildings	$8	$34,533	....	$153,085	$107,883	$6,250	....	$17,581	$75	$6,695	....	$3,309	$329,419
Hospitals, institutions	1,450	1,054	$18,288	....	10,996	4,400	$182,643	....	205	35,836	....	3,660	258,532
Schools and colleges	142,379	496,862	14,576	69,585	51,834	17,832	62,500	112,173	97,156	48,270	$236,400	158,939	1,508,506
Churches	183,205	36,220	54,137	103,068	122,179	12,625	370,956	15,174	11,850	15,974	10,500	124,862	1,060,750
Theatres, including motion pictures	171,382	1,870	29,542	52,500	336,460	24,438	53,416	7,347	1,954	1,172	150	12,417	692,648
Amusements, halls	89,982	46,479	28,245	....	201,920	1,188	148,122	....	5,375	4,461	23,133	27,077	575,982
II. Dwelling Occupancies													
Hotels, boarding houses	117,931	8,050	9,464	5,955	344,684	6,318	42,945	113,524	14,880*g*	6,918	16,950	96,566	784,185
Apartments, rooming houses	187,560	274,672	72,870	....	....	4,411	304,607	....	3,336	140	88,000	31,678	967,274
Dwellings	2,670,032	1,478,026	1,057,906	330,482*a*	3,546,481	411,515	2,873,098	1,103,774	108,959	792,473*d*	350,721	1,805,315	16,528,782
III. Mercantiles													
Office bldgs., including banks	124,549	29,976	13,956	....	989,906	6,745	41,791	....	1,053	3,023	15,580	19,991	1,246,570
Restaurants, taverns	246,036	48,432	40,779	....	402,349	35,867	....	45,023	....	4,639	7,075	225,483	1,055,683
Barber, beauty shops	4,422	....	1,263	....	8,451	980	....	....	....	....	150	3,475	18,741
Misc. mercantiles	2,046,321	642,235	492,291	327,124*b*	2,146,943	333,830	963,854	1,111,472*b*	101,844	92,209	524,669	852,788	9,635,580
Warehouses	1,585,516	111,945	118,351	....	614,384	3,697	1,795,014	73,448	....	3,326	47,800	290,040	4,643,521
IV. Manufacturing													
Metal workers	106,725	2,410	35,495	4,374	50,142	....	....	66,665	290	1,504	17,500	39,191	324,296
Woodworkers	75,050	16,421	6,503	....	31,158	....	....	1,143,093	2,550	42,068	....	214,865	1,531,708
Flour mills, elevators	174,796	118,395	170,160	110,293	....	334,755	....	163,122	53,828	31,979	....	1,253,717	2,411,045
Packing plants, stockyards	3,900	115,377	18,992	....	....	441	....	....	10,600	1,500	....	970	151,780
Bakeries	7,135	10,744	2,744	....	11,860	130	....	244,967	....	1,137	....	16,954	295,671
Laundries	65,315	61,656	31,084	....	57,224	....	76,816	135,602	360	1,348	500	7,768	437,673
Cleaners, tailors	3,153	31,421	4,924	4,545*c*	64,533	87	38,606	....	1,860	....	35,600	2,851	187,580
Misc. manufacturing	1,170,210	543,351	543,637	105,886	2,150,994	95,170	2,299,391	148,368	15,210	13,627	151,986	570,491	7,808,321
V. Miscellaneous													
Barns	802,793	483,832	386,906*d*	302,559*d*	394,038	124,368	623,629	249,312*f*	86,491*f*	....	37,987	664,448	4,156,363
Outbuildings	162,509	158,945	57,803	....	58,840	190,577	92,880	....	....	400	7,715	96,678	826,347
Lumber and coal yards	139,045	74,821	57,457	450	123,625	9,104	45,191	....	91,340	2,473	....	14,917	558,423
Railroads, wharves	64,469	4,660	6,116	1,695	22,202	1,332	....	1,535	563	....	1,650	32,519	136,741
Bulk oil storage, refineries	157,524	68,121	5,329	24,656*e*	....	12,455	....	13,533	1,263	....	....	....	282,881
Garages, filling stations	326,183	483,806	139,611	1,000	311,239	159,656	362,421	16,772	57,465	16,042	48,616	111,881	2,034,692
Power plants, pump houses	46,905	17,220	6,353	....	17,103	24,199	....	25,890	1,610	1,109	....	29,767	170,156
Creameries, dairies	....	7,486	11,333	....	....	1,849	....	27,803	558	....	....	17,482	66,511
Miscellaneous structures	373,080	44,323	121,203	17,810	454,126	22,760	1,286,643	108	1,400	426	....	6,132	2,328,011
Motor vehicles	189,092	41,397	39,357	24,663	70,411	22,773	179,435	51,592	9,775	....	17,985	111,292	757,772
Fires other than structures	58,257	70,103	5,476	21,113	13,545	28,510	....	15	7,581	....	....	136,233	340,833
Hangars and contents	....	275	....	43,342	10,000	10,000	....	....	5,828	3,500	....	28,643	101,588

*Insurance losses only.
†Fiscal year ending June 30, 1942.
a. Does not include farm property.
b. Includes office buildings.
c. Includes cloth and textile workers.
d. Includes all farm property.
e. Includes filling stations.
f. Includes outbuildings.
g. Includes restaurants.

Table III. Number of Fires by Causes in Twelve States — 1942.

Causes	Illinois	Indiana†	Iowa	Kansas	Massachusetts	Nebraska	Ohio	Oregon*	South Dakota†	Vermont	West Virginia	Wisconsin	Total
Chimneys, flues — defective, overheated	1,022	397	336	118	552	176	1,904	615	64	130	56	1,605	6,975
Sparks on roofs	1,266	515	627	174	157	158	2,213	414	....	4	1	631	6,160
Defective or overheated heating equipment	1,417	92	162	324	190	....	2,419	854	34	73	39	710	6,314
Rubbish	1,096	135	15	39	....	....	733	35	75	15	4	123	2,270
Combustibles near heaters	....	....	23	....	298	3	....	....	....	....	3	105	432
Open lights, flames, sparks	494	122	224	67	187	261	680	522	56	16	2	574	3,205
Hot ashes, coals	258	304	37	135	123	40	421	....	16	24	2	224	1,584
Oil burners	....	88	13	....	470	....	....	....	13	....	....	284	868
Smoking and matches	2,558	492	406	226	2,780	292	4,793	1,801	70	61	19	3,286	16,784
Children and matches	....	....	103	....	434	155	927	....	41	....	9	304	1,973
Electrical	1,990	290	178	215	1,083	157	2,591	397	103	38	26	1,157	8,225
Electrical appliances, motors	121	21	174	26	55	131	555	252	16	5	....	581	1,937
Flammable liquids, home dry cleaning, starting fires	992	65	91	97	394	80	1,076	146	2	54	....	426	3,423
Torches, welding	....	32	41	....	68	23	100	....	14	....	2	58	338
Films	....	3	4	....	....	4	28	....	2	....	....	3	44
Lamps and stoves	....	357	185	....	363	350	....	....	109	....	5	682	2,051
Gas and appliances	125	111	7	20	9	....	232	....	....	2	11	124	641
Grease, tar, etc.	172	....	39	45	173	60	310	355	....	10	1	428	1,593
Spontaneous ignition	442	135	132	43	348	165	708	65	37	20	6	237	2,338
Fireworks	3	....	1	13	2	7	....	1	1	....	....	19	47
Lightning	360	98	105	52	72	64	99	78	33	50	9	5,254	6,274
Thawing pipes	....	42	5	....	79	....	....	....	1	....	9	24	160
Sparks from machinery, friction	34	9	12	16	41	....	....	34	....	14	....	28	188
Incendiary, suspicious	57	14	18	7	267	15	136	11	5	3	14	26	573
Miscellaneous	507	142	332	80	33	36	1,278	502	48	5	2	252	3,217
Unknown	1,318	905	439	616	288	190	1,631	1,076	86	253	237	652	7,691
Explosions	173	190	....	18	....	....	....	74	24	3	....	109	591
Exposure	763	75	157	81	224	36	527	236	26	32	19	250	2,426

*Includes additional insurance claims on contents.
†Fiscal year ending June 30, 1942.

Table IV. Fire Loss by Causes in Twelve States — 1942.

Causes	Illinois	Indiana†	Iowa	Kansas	Massachusetts	Nebraska	Ohio	Oregon*	South Dakota†	Vermont	West Virginia	Wisconsin	Total
Chimneys, flues — defective, overheated	$368,445	$258,954	$219,942	$56,279	$417,130	$89,065	$528,522	$223,864	$26,368	$78,223	$65,952	$408,995	$2,741,739
Sparks on roofs	396,674	215,257	191,658	49,497	66,176	28,812	352,947	117,019	....	4,254	51,000	287,656	1,760,950
Defective or overheated heating equipment	774,469	69,016	153,562	143,437	286,151	....	896,633	353,751	68,996	54,159	57,245	507,209	3,364,628
Rubbish	60,447	155,549	5,525	14,309	....	....	137,094	4,257	8,509	5,646	1,450	32,868	425,654
Combustibles near heaters	....	....	3,769	....	273,548	102	....	....	....	....	3,458	8,495	289,372
Open lights, flames, sparks	301,853	35,867	92,884	9,824	131,073	68,100	396,922	39,711	12,537	7,597	800	208,480	1,305,648
Hot ashes, coals	68,602	310,386	7,540	29,294	119,642	9,359	154,679	....	1,716	8,813	2,660	56,193	768,884
Oil burners	....	25,986	23,600	....	501,305	....	....	....	1,348	....	....	83,904	636,143
Smoking and matches	323,860	149,678	90,897	46,204	2,808,481	297,250	1,163,735	144,873	18,049	17,085	19,763	174,513	5,254,388
Children and matches	....	....	12,922	....	274,007	39,627	122,917	....	10,310	....	24,965	69,847	554,595
Electrical	1,072,640	505,466	263,440	112,859	2,184,484	124,459	688,592	294,571	144,577	31,055	277,628	813,070	6,512,841
Electrical appliances, motors	34,326	6,858	90,833	6,808	13,328	174,947	76,431	123,650	2,777	14,460	....	58,561	602,979
Flammable liquids, home dry cleaning, starting fires	449,951	29,527	91,161	40,626	329,588	77,130	437,141	30,616	1,167	36,797	....	126,700	1,650,404
Torches, welding	....	15,359	10,952	....	69,384	18,848	108,299	....	5,132	....	6,050	14,824	248,848
Films	....	1,547	1,688	....	....	7,988	3,332	....	240	....	....	665	15,460
Lamps and stoves	....	364,980	66,942	....	581,156	91,552	....	....	52,454	....	6,670	162,549	1,326,303
Gas and appliances	348,353	28,104	5,510	8,727	1,943	....	61,302	....	....	375	18,335	83,695	556,344
Grease, tar, etc.	69,340	....	14,748	16,369	163,905	5,792	114,782	20,953	....	1,346	550	38,110	445,895
Spontaneous ignition	262,851	194,121	234,686	44,776	918,215	90,133	593,276	63,489	26,935	69,855	6,338	275,957	2,780,632
Fireworks	350	....	41	386	60	2,450	....	22	50	....	....	1,176	4,535
Lightning	570,696	227,001	158,218	41,340	71,562	39,757	158,322	12,530	19,451	72,746	14,875	806,936	2,193,434
Thawing pipes	....	23,758	144	....	41,571	....	....	....	25	....	2,425	17,289	85,212
Sparks from machinery, friction	41,212	38,410	12,071	7,820	25,406	....	....	60,656	....	23,931	....	7,127	216,633
Incendiary, suspicious	202,650	20,432	7,828	160,510	615,715	16,765	102,446	15,010	3,147	38,371	125,980	45,654	1,354,508
Miscellaneous	243,224	51,400	498,181	111,121	27,622	17,747	1,260,032	58,167	6,016	3,578	2,150	46,130	2,325,368
Unknown	4,331,422	2,552,388	1,186,045	756,141	2,804,504	564,042	4,332,261	2,736,350	247,179	629,504	866,618	1,064,128	22,070,582
Explosions	164,572	147,769	....	6,260	....	....	....	46,680	12,810	3,562	....	1,362,140	1,743,793
Exposure	1,410,977	134,805	157,364	41,598	601,093	75,311	154,293	541,724	25,469	30,892	85,755	249,537	3,508,818

*Insurance losses only.
†Fiscal year ending June 30, 1942.

Table VI shows the total estimated number of fires and fire losses distributed by occupancies and based on the data in the previous tables. Table VII shows similar figures by causes. These occupancy and cause classifications are not listed in any order of importance, but are grouped so that similar classes come together. Each class is broad in scope in order to reduce the number of classes to a minimum and permit the compilation of a sufficient amount of data on each to be of value. Several of the fire marshals' reports use much longer lists of occupancies and causes by subdividing the general classes shown in the accompanying tables. For example, some states divide the occupancy class "Dwellings" into "City Dwellings" and "Farm Dwellings," and the cause class "Lightning" into "Rodded" and "Unrodded."

To arrive at the estimates shown in Tables VI and VII the procedure outlined above was applied to the figures for each class in previous tables, except for those classes where data were lacking from several states. In such instances proportional increases in the total estimates were made. For example, some states did not give fires in "Barber, beauty shops," and the estimate of the total number of barber and beauty shop fires was therefore adjusted in accordance with the number of states reporting. A corresponding reduction was then made in other classes. In this particular example the "Miscellaneous" and "Mercantile" classes were reduced, as it is likely that the states not reporting barber and beauty shops used these classes for recording such fires.

Table V. Fires per 1000 Population and Fire Loss per Person for Twelve States, 1942, as Reported by Fire Marshals.

State	Population 1940 Census	Number Fires	Fires per 1000 Pop.	Fire Loss	Fire Loss Per Person
Illinois	7,897,241	15,168	1.93	$11,496,914(3)	$1.46(3)
Indiana	3,427,796	4,634(4)	1.35	5,562,618(4)	1.62
Iowa	2,538,268	3,866	1.52	3,602,151	1.42
Kansas	1,801,028	2,412	1.34	1,704,185	0.95
Massachusetts	4,316,721	8,466	1.96	12,725,957	2.94
Nebraska	1,315,834	2,552	1.94	1,908,262(2)	1.45
Ohio	6,907,612	23,361	3.39	11,843,958	1.71
Oregon	1,089,684	7,468(1)	6.86(1)	4,887,893	4.48
South Dakota	642,961	876(4)	1.36	695,259(4)	1.08
Vermont	359,231	812	2.27	1,132,249	3.15
West Virginia	1,901,974	476	2.51	1,640,667	0.87
Wisconsin	3,137,587	18,156	5.80	7,012,408	2.23
Total	35,335,937	88,217	2.52	$64,212,521(3)	$2.07(3)
Estimated U. S. Total	131,669,275	665,000	5.05	$315,000,000*	$2.39

(1) Includes total insurance claims.
(2) As reported by fire chiefs.
(3) Chicago losses not included.
(4) Fiscal year ending June 30, 1942.
*30% added for unreported losses.

Table VI. Estimated Distribution of U. S. Fire Losses by Occupancies, 1942.

These estimated figures are intended to show the relative order of magnitude of fire losses by occupancies, and while they are reasonable approximations based on the experience in typical states they should not be taken as exact records for each class.

Occupancy	No. of Fires	Loss
I. Public Buildings		
Government buildings	900	$1,000,000
Hospitals, institutions	1,000	1,500,000
Schools and colleges	2,400	7,300,000
Churches	2,800	5,100,000
Theatres, including motion pictures	1,400	2,500,000
Amusements, halls	2,600	3,000,000
II. Dwelling Occupancies		
Hotels, boarding houses	7,800	3,800,000
Apartments, rooming houses	47,000	5,800,000
Dwellings	322,000	80,000,000
III. Mercantile		
Office buildings, including banks	5,800	7,400,000
Restaurants, taverns	10,000	6,900,000
Barber, beauty shops	900	200,000
Miscellaneous mercantiles	42,000	38,000,000
Warehouses	6,700	24,000,000
IV. Manufacturing		
Metal workers	2,000	2,000,000
Woodworkers	1,500	7,300,000
Flour mills, elevators	2,100	9,500,000
Packing plants	800	1,500,000
Bakeries	1,200	1,000,000
Laundries	1,400	1,500,000
Cleaners, tailors	1,400	900,000
Miscellaneous manufacturing	19,000	40,000,000
V. Miscellaneous		
Barns	20,000	21,000,000
Outbuildings	20,000	3,300,000
Lumber and coal yards	1,400	4,000,000
Railroad, wharf property	4,600	5,900,000
Bulk oil storage, refineries	1,500	2,600,000
Garages, filling stations	28,500	9,500,000
Power plants, pump houses	1,700	1,200,000
Creameries and dairies	2,000	600,000
Miscellaneous structures	17,400	9,700,000
Motor vehicles, including aircraft	64,000	3,700,000
Fires other than structures	21,000	2,200,000
Hangars and contents	200	1,100,000
Totals	665,000	$315,000,000

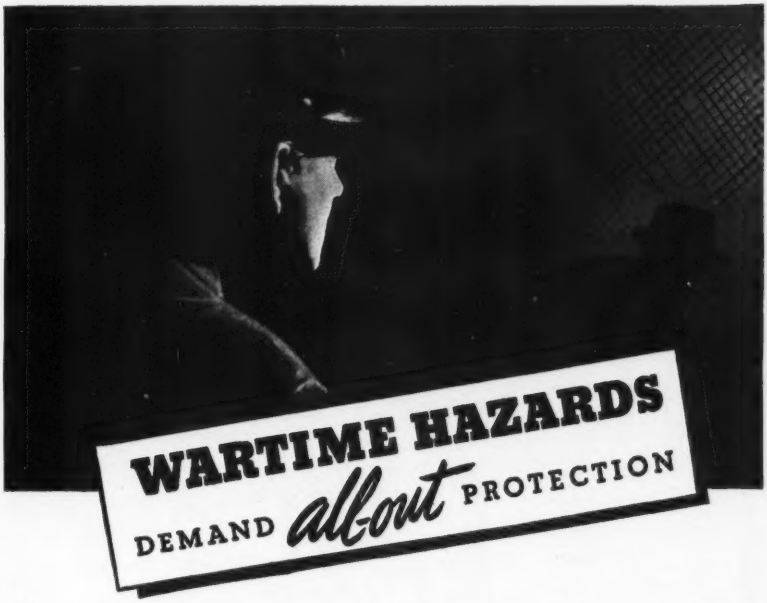
Note: As explained in the text, 100 per cent has been added in estimating the number of fires, and 30 per cent has been added to the losses to cover unreported losses.

Table VII. Estimated Distribution of U. S. Fire Losses by Causes — 1942.

These estimated figures are intended to show the relative order of magnitude of fire losses by causes, and while they are reasonable approximations based on the experience in typical states they should not be taken as exact records for each class.

Cause	No. of Fires	Loss
Chimneys, flues—defective or overheated	50,000	$12,500,000
Sparks on roofs	44,000	9,000,000
Defective or overheated heating equipment	45,000	15,000,000
Rubbish	19,000	2,400,000
Combustibles near heaters	8,000	3,500,000
Open lights, flames, sparks	25,000	7,000,000
Hot ashes, coals	11,500	3,500,000
Oil burners	12,000	7,500,000
Smoking and matches	130,000	20,000,000
Children and matches	23,500	4,000,000
Electrical	58,000	25,000,000
Electrical appliances, motors	15,000	3,000,000
Flammable liquids, misc., including home dry cleaning and starting fires with	25,500	8,500,000
Torches, welding, cutting, plumbers', etc.	3,500	2,000,000
Films, nitrocellulose	500	150,000
Lamps, lanterns, and stoves	15,500	10,000,000
Gas and appliances	5,000	2,500,000
Grease, tar, etc.	12,500	2,500,000
Spontaneous ignition	17,000	13,500,000
Fireworks	500	50,000
Lightning	33,000	10,500,000
Thawing pipes	2,500	900,000
Sparks from machinery, friction	2,000	1,500,000
Incendiary, suspicious	4,000	6,500,000
Miscellaneous	23,000	11,000,000
Unknown	54,000	107,000,000
Explosions	8,000	11,000,000
Exposure	17,500	15,000,000
Totals	665,000	$315,000,000

NOTE: As explained in the text, 100 per cent has been added in estimating the number of fires, and 30 per cent has been added to the losses to cover unreported losses.



WITH THE THREAT of sabotage added to all the hazards of normal times, all-out protection against fire and unlawful intrusion is a "must" in every industrial establishment.

All-out protection demands supplementing protective manpower with systems that function *automatically*, such as electrically supervised automatic sprinklers, automatic fire alarms, burglar alarms and other automatic intrusion detection systems. Watchmen and guards require the additional support of an outside central station which maintains a continuous check on their activities and provides prompt aid in emergencies.

Thousands of war plants now receive this all-out protection through A.D.T. Central Station Automatic Electric Protection Services. Available in more than 650 cities and towns in the United States, this type of service assures the complete dependability and efficiency of operation which is essential to any "all-out" protection program.

Write for descriptive booklets.

A.D.T. CENTRAL STATION ELECTRIC PROTECTION SERVICES

Controlled Companies of **AMERICAN DISTRICT TELEGRAPH CO.** *155 Sixth Ave., New York*
CENTRAL STATION OFFICES IN ALL PRINCIPAL CITIES OF THE U. S.

A·D·T
Electric Protection Services
AGAINST FIRE · BURGLARY · HOLDUP
A NATION-WIDE ORGANIZATION

GUNS!
BULLETS!
SPRINKLERS!

Vital Wartime Essentials! Star Automatic Sprinklers defeat the saboteur whose chief weapon is fire — Combat our enemies by guaranteeing uninterrupted war production — Preserve critical materials for our armed forces — Protect the assets of our Nation!

Automatic Sprinklers
Corrosion-proof Sprinklers
Directional Flow Sprinklers
Open Sprinklers
Ornamental Sprinklers
Alarm Devices

Automatic Releases
Alarm Valve (Wet) Systems
Dry Pipe Valve Systems
Deluge Systems
Heat-Actuating Devices
Pre-Action Systems

Star Automatic Sprinklers and Fire Protection Devices bear approval of all Insurance Authorities having jurisdiction and various Governmental Agencies.

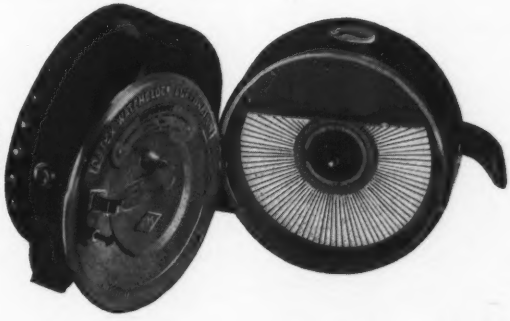
Economy in installation cost and maintenance has dictated the consistent policy of Star Sprinkler Corporation in distributing its Fire Protection Devices through local licensed contractors who have had a lifetime of experience in the installation of automatic sprinkler systems. Operating throughout the United States, Canada and South America, Star licensees, due to their strategic locations, can render instant service. Write us for name and address of Star licensed contractor nearest your location.

STAR SPRINKLER CORP.

Westmoreland and Collins Sts. - Philadelphia, Pa.

There are no Ifs or Buts —when your Guard or Watchman carries a DETEX Watchclock.

The Dial records his activities . . . gives proof of his attention (or inattention) to duty. Investigate DETEX today.



DETEX WATCHCLOCK CORPORATION

84 Varick Street, New York
4163 Ravenswood Avenue, Chicago
31 Beach Street, Boston
122 Marietta Street, Atlanta

DETEX WATCHMENS CLOCKS

NEWMAN • ECO • ALERT • PATROL

WARTIME • PEACETIME • ALL THE TIME

HOFFMAN 140-F IS THE

The Hoffman 140-F Drycleaning Unit is approved by the National Board of Fire Underwriters as a Class II Unit—for use in conjunction with listed petroleum solvents having a flash point of 138.2°F. or over. The war shortage of chlorine has had no effect upon the legitimate operations of drycleaners using this equipment and solvent. Hoffman 140-F still provides approved, safe drycleaning operations.

U. S. HOFFMAN MACHINERY CORPORATION
105 Fourth Ave., New York 3, N.Y.
DRY CLEANING, LAUNDRY & GARMENT PRESSING EQUIPMENT

For years, carbon dioxide gas, the fastest non-damaging fire extinguishing agent, was released from portable cylinders by turning a hand-wheel valve. C-O-TWO now offers the sensational SQUEEZE-GRIP valve that releases carbon dioxide as fast as you can close your hand on the release lever. It has these remarkable advantages over the old hand-wheel valve:

A — No need to set the extinguisher down to open or close the SQUEEZ-GRIP valve. Hold it, aim it, squeeze it.

B — Squeeze the lever over the carrying handle. SQUEEZ-GRIP valve opens. Release, and the valve closes.

C — Positive control of the flow of gas while carrying the extinguisher with one hand; other hand free to aim the discharge horn.

C-O-TWO FIRE EQUIPMENT COMPANY

NEWARK 1, NEW JERSEY

Sales and Service in the Principal Cities of United States and Canada

FIRE CONTROL

MIGHTY FOR WAR SUPREMACY

FIRE CONTROL INSTRUMENTS in battle are used by our superb gunners on battleships—on coast defenses and of the artillery to hit targets they cannot see and for equal accuracy, speed and efficiency—

FIRE CONTROL — AUTOMATIC SPRINKLERS in the work world without human aid hit and kill the target fire and keep industrial production flowing.

WAR accentuates the destructive side of FIRE and both of these FIRE CONTROLS in their respective fields are recognized as *indispensable.*

On high authority the statement is made that the War Program is menaced by preventable fire losses and that these are as grave as if wrought by enemy bombs or saboteurs. Wherever an essential industry is interrupted, it prolongs the period of "BLOOD, SWEAT AND TEARS."

The natural enemy of FIRE is an advance design line of approved GLOBE SPRINKLER APPARATUS for AUTOMATIC FIRE CONTROL — the result of nearly 50 years' research and development.

GLOBE devices embody the maximum of engineering ingenuity with a minimum of critical materials. They are approved by all government and insurance authorities. They are essential during the war and the post-war era.

GLOBE

Automatic Sprinkler Co.

2035 WASHINGTON AVENUE

Philadelphia, Pa.

SALES OFFICES IN PRINCIPAL CITIES

Ready for the Signal to *Bomb and Destroy*

Official U.S. Navy Photograph

"A Navy war bird awaits the starter's signal to take off for the combat zone."

BOMBERS and Carriers are powerful media of destruction but still they must be protected. The Carrier must be kept safe for the homecoming of this Navy war bird—safe from enemy shells and incendiary bombs.

Guns to fend attacks from the sea and air and, equally important, adequate fire protection to quickly extinguish that dread foe, "a fire on ship at sea."

National Foams have met the extreme tests in combating fires at sea, saving lives and tonnage to carry on.

Foam Fire Protection as developed by National Foam System has been adopted and is being used extensively by the U. S. Navy, by most oil refineries and many other important industries.

In Fire Department Service

National Foam System has equipment especially designed for the use of Fire Departments to meet all types of fire fighting requirements. Complete engineering service available.

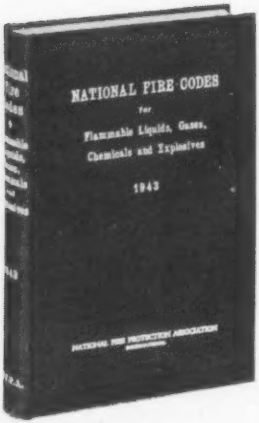
The experience of our engineering department is at your service.

NATIONAL FOAM SYSTEM, INC.

Specializing in Foam Fire Protection

1632 Sansom St., Philadelphia, Pa.

Announcing



NATIONAL FIRE CODES *for*

FLAMMABLE LIQUIDS, GASES, CHEMICALS AND EXPLOSIVES

This 500-page volume brings together for convenient reference the many standards dealing with flammable liquids, gases, chemicals and explosives. The number and diversity of these standards has become so great that it is increasingly difficult for the average user, who is interested in a wide variety of subjects, to keep track of all the standards in separate small pamphlet form.

Price $3.00 POSTPAID

Indispensable for fire chiefs and other fire department officers; fire marshals; fire inspectors; firemen; consulting engineers; building commissioners and inspectors; various other state and local administrative authorities; industrial fire protection and safety engineers; industrial executives; technologists in petroleum, gas, and chemical industries; insurance companies, engineers and inspectors; state, local, and special insurance agents and brokers; universities; libraries, etc.

Place Your Order Now!

NATIONAL FIRE PROTECTION ASSOCIATION
INTERNATIONAL
60 Batterymarch St., Boston 10, Mass.

New Fire-Killing Power for Dugas

DuGas, well known for its fast action in extinguishing difficult fires, now makes an important new contribution to fire protection. Research has resulted in the development of a new PLUS-FIFTY duGas Dry Chemical with increased fire-fighting effectiveness when applied from duGas pressure-type dry chemical extinguishers. This new, faster action is obtained without sacrificing any of the advantages of the former duGas.

APPROVED by the Underwriters' Laboratories and the Factory Mutual Laboratories.

AVAILABLE in Models 15 and 30 Hand Extinguishers, Models 150 and 350 Wheeled Extinguishers.

...WRITE FOR COMPLETE BULLETIN ON NEW PLUS-FIFTY DUGAS and Priority Information on Extinguishing Equipment.

Proven by Hundreds of Practical Fire Tests

It retains the long-range effectiveness of the stream which permits the operator to knock down fire from a greater distance. It hangs in a cloud over the fire, providing greater smothering action and reducing flashbacks. Like the former duGas, PLUS-FIFTY duGas will not cake, harden, evaporate, deteriorate or freeze. It generates no toxic fumes and is not an electrical conductor. Since no critical materials are used in its production, PLUS-FIFTY duGas is available without priority for refill purposes...and there is no advance in price.

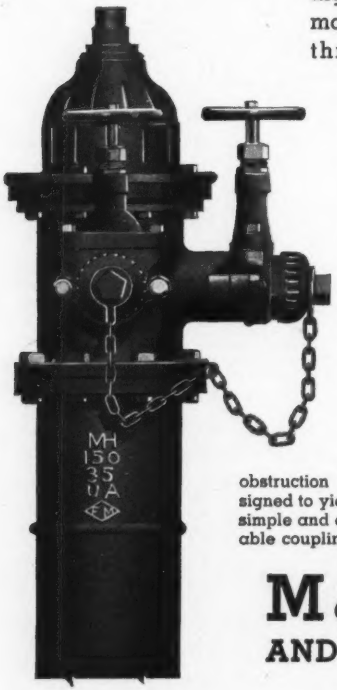
Model 150
Wheeled Extinguisher

WRITE FOR
Chart showing characteristics of *all* types of approved hand fire extinguishers.

DUGAS ENGINEERING CORPORATION

Fire-Fighters Appreciate

VALVES
HYDRANTS
AND PIPE LINE ACCESSORIES



M & H products are well known for high quality material and expert workmanship. They have been widely used throughout the country for many years. They include several types of Gate Valves, Check Valves, Flap Valves, Valve Boxes, B & S Fittings, Flanged Fittings, Fire Hydrants and many other cast iron pipe line accessories.

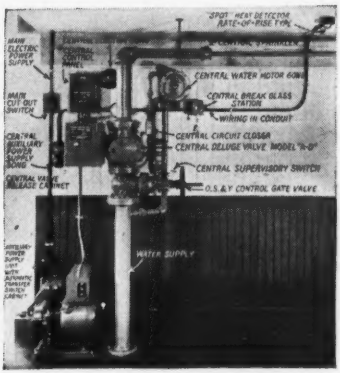
AWWA & UNDERWRITERS APPROVED FIRE HYDRANTS

M & H Fire Hydrants are dry top and revolving head. They are easy to lubricate. Maintenance costs are low due to simplicity of design and rugged construction. They have low friction loss and great efficiency because barrel diameter is not reduced and there are no working parts or obstruction in waterway. Special Traffic model is designed to yield at the ground line under impact. Repair is simple and easy by renewing breakable bolts and breakable coupling on stem.

M&H VALVE
AND FITTINGS COMPANY
ANNISTON, ALABAMA

Introducing

Central "Electro-Speed" Deluge Sprinkler System Model "AD"



Completely Electrically Operated

• • •

Rate of Rise and Fixed Temperature Controlled

• • •

Fully Supervised

"A PRODUCT OF THE ELECTRONIC AGE"

Over three years ago we pioneered the first Underwriters approved electrically operated deluge type automatic sprinkler system. We now present, in the CENTRAL Model "AD" Electro-Speed Sprinkler System, a completely new and all electrically operated system, amazing in its simplicity of design and in its instantaneous super-speed electric operation.

Every functional part is a standard product with years of dependable use to insure for you satisfactory and continued service.

Already about one hundred CENTRAL Model "AD" Deluge Sprinkler Systems are now in service protecting vital United States Army and Navy, and privately owned properties, and proving their superior design and operation over older types of deluge systems in adjacent buildings in some of these properties.

Send for illustrated and descriptive bulletin N.P.-V-4.

CENTRAL AUTOMATIC SPRINKLER CO.

241 EAST ASHMEAD STREET . . PHILADELPHIA, PA.

RE-FUELING

Refuelling planes is a service that must be performed safely and with dispatch. Because of military urgency, tremendous investment in equipment, and the hazard to highly trained personnel—there must be no mistakes.

The S. & J. Automatic Tank Gauge, applicable to mechanical pumping or water displacement types of storage expedites the safe fuelling of military and civilian craft. It is float operated and gives an accurate, direct dial reading.

The S. & J. Figure ST-3600 Dial Gauge can be supplied with an electric level alarm or pump controller as shown below, which may be used to sound an alarm or light a signal, or may be employed as an electric control on the pump or engine.

Complete details will be furnished to those entitled to the information.

SHAND & JURS CO.

BERKELEY, CALIFORNIA

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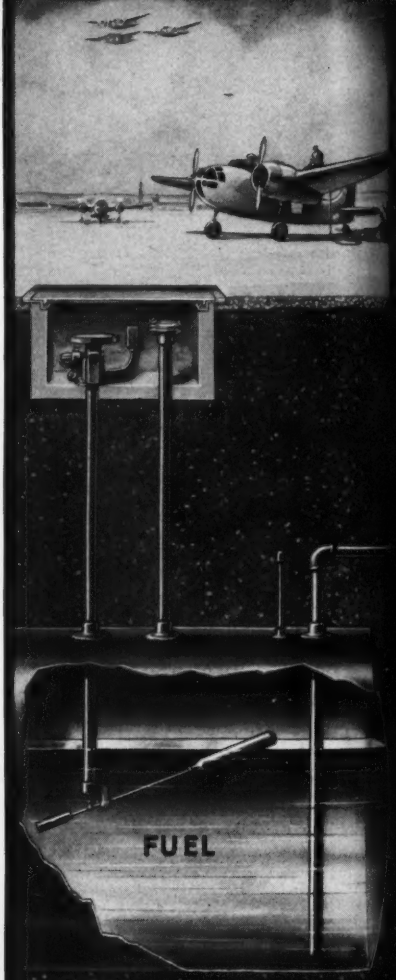
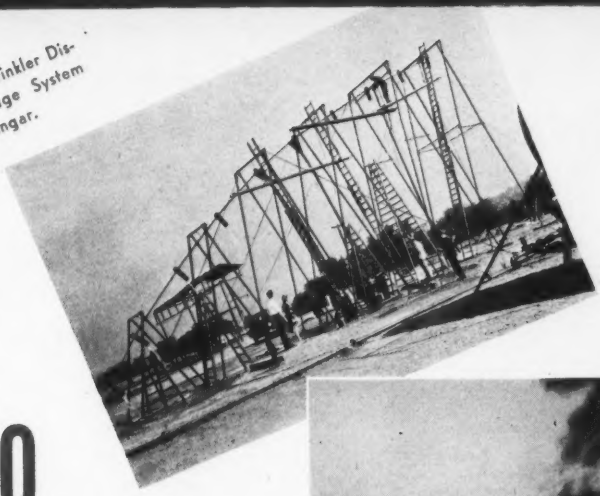
Figure ST-3600
Automatic Tank Gauge



SHAND & JURS



• Checking Sprinkler Discharge for Deluge System in Airplane Hangar.

NO RULE-OF-THUMB!

"Automatic" Sprinkler Systems are designed after Research and Tests

• Flammable Liquid Fire Test.

AMERICAN genius is creating remarkable new materials for war—and with them are developing new and unheard-of fire hazards. Our job is to help control these hazards—from flammable liquids, synthetic rubber compounds, gun powder, nitrocellulose film, etc. . . . . .

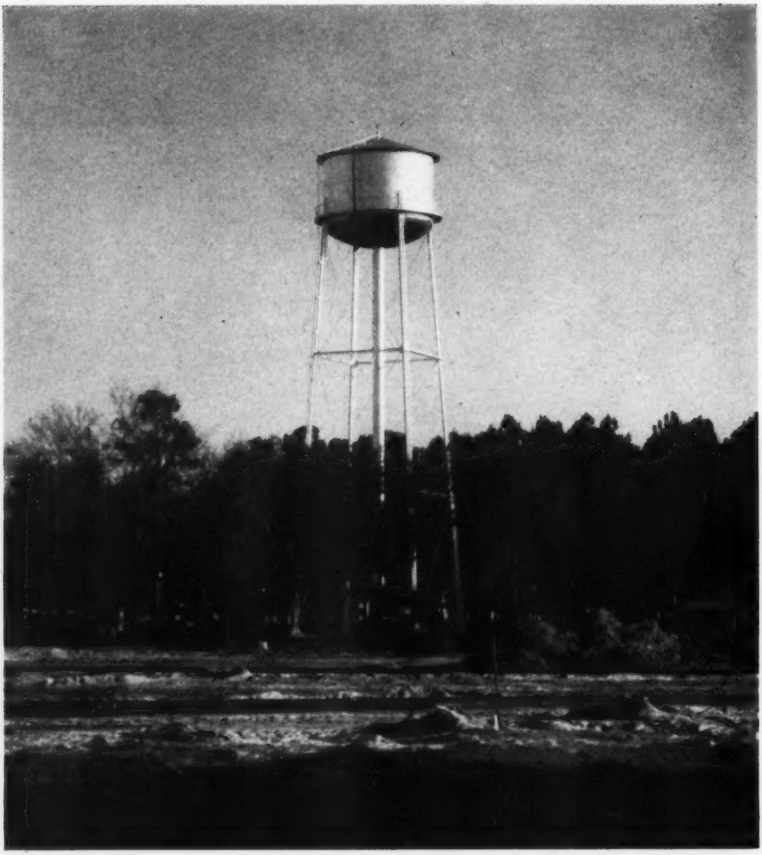
In meeting this need, our research and pre-testing facilities have been expanded and are in daily use. Simulating existing conditions, experimental test setups are constructed with piping and sprinklers, for extinguishing fires in actual materials, and for checking hydraulic calculations. One day a test is being conducted on a FIRE-FOG System for flammable liquid, another on a High Speed Deluge System for smokeless powder, and again on a Suprotex-Deluge System for some airplane hangar.

All tests and experimental work are in collaboration with engineers of fire insurance companies, industrial firms and Army and Navy. All theory and practice are thoroughly checked and tested before an "Automatic" Sprinkler System is built.

• • •

"AUTOMATIC" SPRINKLER CORP. OF AMERICA

YOUNGSTOWN, OHIO • OFFICES IN PRINCIPAL CITIES



Guarding Against Further Shortage

The shortage of paper is beginning to be felt throughout all industry. A disastrous fire in one of our paper mills would cut an inadequate production seriously. At many paper mills, elevated water tanks like this 100,000-gal. installation are guarding against catastrophe by providing gravity water pressure for automatic sprinkler systems.

CHICAGO BRIDGE & IRON COMPANY

CLEVELAND	CHICAGO	BIRMINGHAM	NEW YORK
WASHINGTON	HAVANA	GREENVILLE, PA.	PHILADELPHIA
HOUSTON	HILLSIDE, N. J.	TULSA	SAN FRANCISCO

HOME OWNERS APPRECIATE THIS INFORMATION

What types of fire fighting equipment are effective for ordinary grass fires? What types for flammable liquid and grease fires? What types for electrical fires? The answers to these and other questions regarding the protection of property from fire in wartime are given in this folder, "Fire Defense For Your Home In Wartime." Send for a copy.

AUTOMOBILE INSURANCE COMPANY
STANDARD FIRE INSURANCE COMPANY

HARTFORD, CONNECTICUT

Fire and Marine Insurance

Affiliated with Ætna Life Insurance Co., Ætna Casualty and Surety Co.

VIKING

INDUSTRIAL SPRINKLING SYSTEMS *on guard!*

Viking Sprinkler Systems guarding vital War Bases and Plants say "Not Here" to Fire! Today, Viking's entire output is going where the tools of war are made, stored, handled, repaired and used.

Thus in war, as in peace, Viking Sprinkler Systems are proving their dependability. When Viking stands guard, Fire heeds the command "Not Here"! . . . and the tools of war stay fit for their intended job.

VIKING CORPORATION DEALERS

Crawford & Slaten Co.
Atlanta, Georgia
C. W. Hutchinson, Inc.
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THE VIKING CORPORATION
HASTINGS, MICHIGAN

Drop that extinguisher!

. . . unless you want to burn down the plant

The man who hits flaming oil with a soda-acid fire extinguisher is heading for trouble. He is using a good fire-fighter in the wrong spot. *The wrong extinguisher may be more dangerous than no extinguisher at all!*

The facts about fire extinguishers are easily understood, if correctly taught. Best way to teach them is by *demonstrating.* Show your own extinguishers in action against real fires.

"How To Teach Fire Fighting" has been prepared by Walter Kidde & Company to show you how your plant can handle fire-instruction. This illustrated book explains all classes of fires—tells you how to fight each successfully. You'll want a copy, free. Write Walter Kidde & Company, Inc., 1035 Main Street, Belleville, N. J.

Oil-drenched and salt-encrusted,

PYRANOL TRANSFORMERS COME THROUGH UNHARMED

Three Pyranol transformers were in operation on a large tanker when it was torpedoed off the Atlantic coast. For days they lay submerged in oil and salt water, until what was left of the tanker was salvaged. When the ship finally reached dry dock, the transformers were tested and found to be in as good working condition as the day they were installed.*

IT'S HARD to find an application where Pyranol transformers won't fill the bill. The high dielectric strength which they have in common with other liquid-filled transformers makes it easy for them to withstand the effects of lightning and of voltage surges from switching operations.

Install Pyranol Transformers Right Where You Need Them

You can install Pyranol transformers underground, on an overhead platform, on the roof, on the factory floor, indoors or outdoors. The pressure-tight tank protects vital parts from the effects of dust, dirt, and atmospheric moisture—as well as from oil and salt water.

Maintenance Cost Is Low

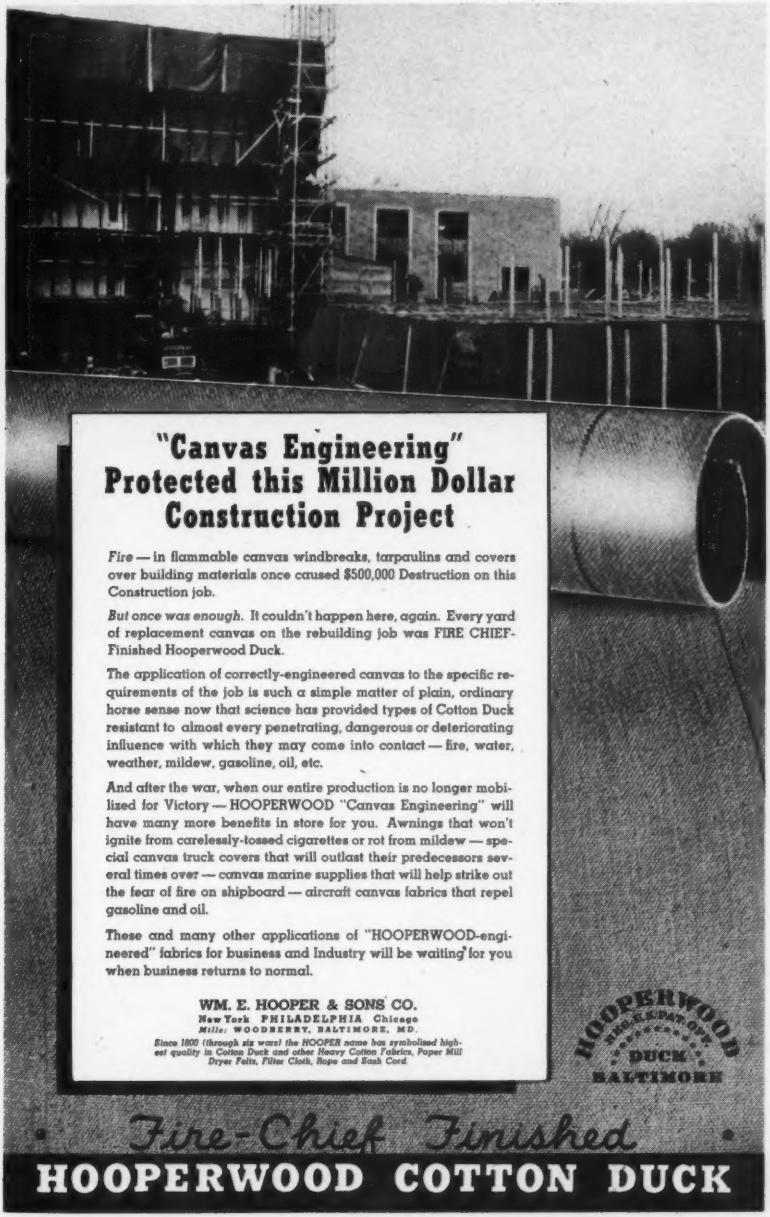
Pyranol, the synthetic, noninflammable insulating and cooling liquid, is nonsludging—maintenance is negligible. Tests show that the Pyranol in the first transformers of this type, installed more than ten years ago, is still in its original condition.

For further information call your G-E representative today. He'll be glad to help you. *General Electric, Schenectady, N. Y.*

**Reg. U.S. Pat. Off.*

GENERAL ELECTRIC

402-58E-5100


"Canvas Engineering"
Protected this Million Dollar
Construction Project
Fire — in flammable canvas windbreaks, tarpaulins and covers over building materials once caused $500,000 Destruction on this Construction job.
But once was enough. It couldn't happen here, again. Every yard of replacement canvas on the rebuilding job was FIRE CHIEF-Finished Hooperwood Duck.
The application of correctly-engineered canvas to the specific requirements of the job is such a simple matter of plain, ordinary horse sense now that science has provided types of Cotton Duck resistant to almost every penetrating, dangerous or deteriorating influence with which they may come into contact — fire, water, weather, mildew, gasoline, oil, etc.
And after the war, when our entire production is no longer mobilized for Victory — HOOPERWOOD "Canvas Engineering" will have many more benefits in store for you. Awnings that won't ignite from carelessly-tossed cigarettes or rot from mildew — special canvas truck covers that will outlast their predecessors several times over — canvas marine supplies that will help strike out the fear of fire on shipboard — aircraft canvas fabrics that repel gasoline and oil.
These and many other applications of "HOOPERWOOD-engineered" fabrics for business and Industry will be waiting for you when business returns to normal.
WM. E. HOOPER & SONS CO.
New York PHILADELPHIA Chicago
Mills: WOODBERRY, BALTIMORE, MD.
Since 1800 (through six wars) the HOOPER name has symbolized highest quality in Cotton Duck and other Heavy Cotton Fabrics, Paper Mill Dryer Felts, Filter Cloth, Rope and Sash Cord.
HOOPERWOOD
DUCK
BALTIMORE
Fire-Chief Finished
HOOPERWOOD COTTON DUCK

It's HEAT ABSORPTION, not WETNESS, that gives water control over fire... SURFACE AREA, not VOLUME, that puts out fires *fast!*
WATER
turned into
WaterFOG

DOOMS *EVEN* OIL FIRES, FAST

You'll find in your physics book that speed of heat exchange increases with surface area exposed to heat. (That's the principle of the radiator and the refrigerating coil, too.)

By transforming water into tiny particles — much finer than spray — Rockwood WaterFOG nozzles multiply many times the total surface area of a given volume of water . . . thus making water (cheap, plentiful) your most efficient fire-fighter on flammable liquid fires!

In addition to *cooling* fires faster, WaterFOG particles, being light, stay longer in the combustion area, instead of plunging into the liquid, agitating it, inciting further vaporization. They float gently onto the surface, absorbing heat from the vapors and from the liquid — and then, turning into steam, they *expand*, smothering the fire!

"Flash-back" is prevented. Costly chemicals are saved. Water damage is lessened. Safe to use on electrical fires. Write for Bulletin 123.

WaterFOG is created by impinging streams from specially-designed Rockwood nozzles —engineered in correct particle size, fog pattern, and velocity for your conditions. Fixed piping installations, hose nozzles and applicators, Rockwood installations approved by Underwriters' Laboratories and Associated Factory Mutuals; used by Navy, Coast Guard, hundreds of industrial plants. *Executives!* colored movie (16 mm.) showing tests of Rockwood WaterFOG is available.

3 WAYS TO PUT OUT FLAMMABLE LIQUID FIRES

1. **Quench the burning vapors**
2. **Lower liquid temperature to retard vaporization**
3. **Diminish supply of oxygen**

WaterFOG does all three . . . with water . . . faster!

ROCKWOOD SPRINKLER COMPANY
56 Harlow Street, Worcester, Mass.
Specialists in Fire Protection Engineering, Equipment and Installation since 1907

ROCKWOOD WaterFOG

WATER, ENGINEERED BY ROCKWOOD, COOLS, CONFINES, SMOTHERS OIL FIRES

WHERE IS THE NEAREST FIRE ALARM BOX?

for FIRE
USE THE NEAREST BOX NO.
AT
and wait for the Firemen
DO YOU KNOW THAT
600,000
fires occur annually in the U.S.A.
10,000
human lives are lost and
100,000
others are seriously injured and
$400,000,000
in property values plus the indirect losses creating a total waste in excess of One Billion dollars are annually destroyed by Fire.
70%
of the fires — and life losses occur in dwellings.
43%
of the commercial establishments destroyed do not rebuild, and the community loses prestige, business, payrolls, taxes and wealth.
50
times its original size is the spread of fire within 9 minutes after inception.
WHEN FIRE OCCURS—
Use the Box IMMEDIATELY
Delayed Alarms are largely responsible for the excessive Fire Loss.
The Box Is Your Best Protection
FIRE DEPARTMENT

INSTRUCTION CARDS

PROMINENTLY DISPLAYED

in every building will inspire "fire consciousness" and proper action when fire occurs. Fire signaling facilities were never more urgently needed, but scarcity of materials necessitates greater dependence upon existing boxes. Their prompt use for fire will conserve national resources.

THE GAMEWELL COMPANY

NEWTON UPPER FALLS, MASSACHUSETTS

When Fire Strikes . . .

Before the war, when fire struck an unprotected industrial plant, it often destroyed or seriously crippled an individual enterprise. Regardless of insurance coverage, valuable records were destroyed, customers were lost, and trained employees sought work elsewhere.

Today, when fire strikes a plant or its vital war materials, it is not just an individual calamity. It is a serious loss to a whole nation at war! Sorely needed supplies and irreplaceable equipment are destroyed . . . man hours are lost . . . the nation's war production program suffers.

There is one sure way to keep a plant producing and helping to win the war. That is to install a Grinnell Automatic Sprinkler System. There is a type of system for every fire hazard. Each is designed to provide the utmost in automatic fire protection for specific conditions. Complete information is available for the asking from any of our offices throughout the country. Grinnell Company, Inc., Executive Offices, Providence, R. I.

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AUTOMATIC SPRINKLER FIRE PROTECTION